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THE STRUCTURE AND DEVELOPMENT OF THE SPOROPHYLLS AND SPORANGIA OF ISOETES.

CONTRIBUTION FROM THE HULL BOTANICAL LABORATORY. XVIII.

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(WITH PLATES XIII–XX)

FEW plants have excited more interest than Isoetes, a small genus of about fifty species, which has been variously classified, and the histology and development of which have been described in the most contradictory manner. It was with the purpose of obtaining, if possible, some data by which to clear up its homologies and relationships, and especially of examining the foundation of a claim made in recent years of its being the point of contact between monocotyledons and vascular cryptogams that the following investigation was undertaken.

The intention at first was to have the work include not only the reproductive parts of the sporophyte, but also the development of the female gametophyte and of the embryo. But so small a proportion of the spores was found capable of germination that the study of the prothallium had to be abandoned; and my

observations of the embryo agree so closely with those of Professor Campbell (4) that it did not seem worth while to publish any drawings. One difference may be noticed here and this part of the subject may be dismissed at once. Campbell says that but three archegonia are formed at first, and only in case none of these are fertilized do others appear. I have found new archegonia appearing even after three embryos had begun to develop, two of which had made considerable growth. It thus appears that sometimes new archegonia may arise even after fertilization.

The species selected for study were *I. echinospora* and *I. Engelmanni*, the former of which was examined more carefully. The material was collected by Mr. Raynal Dodge, of Newburyport, Mass. Part of it was fixed at once, and part after it had been cultivated for some time in the laboratory. The fixing reagents employed were 1 per cent. chrom-acetic acid, and Flemming's weaker solution. After remaining twenty-four hours in one of these fluids it was washed twenty-four hours in water and transferred through graded alcohols and chloroform or xylol to paraffin. The sections were cut 5, 10, or 15μ in thickness and stained in the ordinary way on the slides. Delafield's hæmatoxylin and erythrosin, safranin and gentian violet, Heidenhain's iron-alum-hæmatoxylin, and cyanin and erythrosin were all used with good results except in the case of the megaspore mother cell.

THE STEM.

The technique which is best adapted to an investigation of the development of the sporangia is not very suitable for an examination of the histology of the stem. Accordingly I have not attempted to make an exhaustive study of the latter, or of the vascular bundles of the leaf. Still the arrangement of the stem tissues is so peculiar that a few remarks will not be out of place. There is probably little variation in this respect in the different species. *I. echinospora* and *I. Engelmanni* agree very closely with *I. lacustris* as figured and described by Farmer (1), whose account is the latest and best dealing with the structure

of the vegetative organs. The center of the stem is occupied by a mass of short spiral and reticulated tracheids interspersed especially near the periphery with less numerous parenchymatous cells. The peripheral parenchyma is not sufficiently aggregated or continuous to form a xylem sheath such as occurs in the leaves. The xylem region is surrounded by a ring of tabular cells of glistening white appearance, thick-walled and empty towards the center but thin-walled towards the outside and more or less banded with incomplete layers of starch-containing cells. The cells are arranged in pretty regular radial rows, whether examined in longitudinal or transverse section. This ring is usually designated the prismatic layer, and very frequently, after Russow (1), the phloem. Russow claimed to have traced a continuity between the prismatic layer and the phloem of the leaf. I have not been able to satisfy myself of any organic continuity, but even did it exist it seems to me very questionable whether that would be a sufficient reason to justify Russow's view. No clearly defined sieve-tubes, the essential elements of the phloem, have ever been found either in the stem or in the leaf; and besides the inner cells of the prismatic zone are known to become secondarily thickened and transformed into xylem tracheids. The cells marked *o* in *fig. 5* are in this process of transformation. Does not this indicate, if not a xylem character, at least the undifferentiated nature of the prismatic cells? A transformation of phloem into xylem would be, to say the least, an anomaly. In view of these difficulties to which may be added another—the relation to the cambium—it seems better to drop this application of the word phloem until its justification shall be established on physiological grounds. A small portion of the prismatic layer is shown in *fig. 5*.

Immediately outside the prismatic layer and indistinguishable from it except in the staining and size of the cells, is a zone of meristem which by its active division gives origin outwardly to an immense mass of cortex, and internally adds slowly to the prismatic layer. This zone is the so-called cambium. Its cells contain deeply staining plasmic contents in addition to starch

(*fig. 5*). Whether or not the dividing cylinder is more than one cell-layer in thickness I could not determine.

The cortex is very bulky and consists throughout of isodiametric parenchymatous cells abundantly filled with starch together with a little oil. The cells undergo no divisions, but as they are forced outward by the activity of the cambium they increase very greatly in size (*figs. 6* and *7*). In this way by the growth of the cells in all directions the cortex expands upwards and downwards as well as outwards, and as a result carries up the older leaves to a height considerably above the stem apex. This is illustrated in *fig. 68*, in which the unbroken lines represent the form which the cortex would take if its cells underwent no enlargement as they are pushed out from the cambium, and the dotted lines the form and dimensions which it actually assumes.

The stem apex lies at the base of the conical depression formed in the manner just explained. In small plants it is distinguishable in longitudinal sections as a slight elevation (*fig. 3*); in older plants it is merely a flattened area between the bases of the young leaves (*fig. 4*).

The method of growth of the apical meristem was first correctly described by Hegelmaier (2). Hofmeister (1) had erroneously ascribed it to the segmentation of an apical cell, having been led to that conclusion probably by too exclusive study of young plants. There is neither an apical cell nor such a group of initials as might result from the division of a rectangular apical cell like that of the Marattiaceæ. Only two or three layers of cells show their meristematic nature by their contents. The superficial layer appears to divide only in an anticlinal direction except when young leaves are about to be formed; but this layer, as Hegelmaier showed, can on no account be regarded as a dermatogen.

Although all the species of Isoetes are perennial, only a small portion of the plant persists from year to year. The roots, the leaves, and the bulky cortex are shed or decay annually, and are as often renewed from the stem apex and the meristematic zone which surrounds the small central permanent cylinder.

THE LEAF AND LIGULE.

In its earliest recognizable form the leaf rudiment seen from above is a crescent-shaped band of meristematic cells, curved about the stem apex. Sections show that it arises from the superficial cells of the stem apex, and is soon pushed up into a low broad mass, highest in the middle and inclined inwards. The ligule appears very early, and the leaf becomes distinguishable into a proximal part somewhat triangular in section and destined to bear the sporangium, and a distal part approximately circular in section and destined to become the chlorophyllous region. In correlation with the rapid development of the sporangium, the growth of the leaf is at first almost confined to the basal region. Compare, *e. g.*, the three leaves shown in *fig. 8*; tranverse sections would show the rapid growth of the basal region in a still greater degree. This region continues to widen as the leaf is pushed outward, by the formation of new leaves and the diametral enlargement of the stem; but longitudinally, except for a slight addition below the sporangium, there is only sufficient growth to accommodate the sporangium, velum, and ligule.

When the sporangium is well under way the region of rapid multiplication and growth of cells is transferred to the part above the ligule. The cells here are arranged with beautiful regularity, and growth is so rapid that this soon becomes the most prominent part of the leaf. The maximum diameter, so far as the number of cells is concerned, is speedily attained, and growth thereafter is only in the longitudinal direction. At first every part of the leaf rudiment is meristematic, but in a short time the apex passes over into permanent tissue. This change into permanent tissue progresses gradually downward until finally the whole leaf is involved. For some time a region of ever narrowing extent above the ligule continues in active division, but there is present no sharply marked or persistent meristematic zone, as seems to be implied in Farmer's account. The leaf is still quite small when all cell divisions have practically ceased, and its further elongation, which may amount to

400 or 500 per cent., is accomplished by the growth of the individual cells.

The formation of the air cavities is interesting, since it is comparable in some respects to the differentiation of trabecular and sporogenous tissue in the sporangium. In a leaf such as is represented in cross section in *fig. 9*, there is yet no sign of the air chambers. Increase of diameter is actively going on and the whole leaf is still meristematic. In the leaf shown in *fig. 10* the position of the future air chambers is indicated by four symmetrically placed groups of cells which have lost most of their contents. The peripheral cells of the leaf, the central cells, and four radiating bands which appear in cross section as spokes arranged in the form of the sign + continue to grow and are distinguishable by their larger more densely filled cells. Stained with Delafield's haematoxylin and erythrosin these cells show deep red cytoplasmic contents and large nuclei in which the red staining predominates; while in the areas which are to become air chambers the cytoplasmic contents have almost entirely disappeared, but the nuclei still retaining their chromatin stain intensely with haematoxylin. When only a nuclear stain is employed, such as iron-alum-haematoxylin, the four non-protoplasmic areas are rendered very prominent by their black nuclei. Longitudinal sections show that the regions which are thus sharply distinct in cross section run lengthwise of the leaf in unbroken bands from just above the ligule nearly to the apex, and there are as yet no air cavities.

The air chambers are formed lysigenously. The growing tissues generate a tension in the empty cells, and as a result these are ruptured irregularly, and small cavities appear, separated by diaphragms or plates of cells extending across from the central to the peripheral growing regions. As the leaf elongates, the air cavities increase in size, while the diaphragms drawn farther and farther apart lose their protoplasm to the surrounding cells. When once this splitting into diaphragms and cavities has occurred, it is not repeated; there remains no meristem in which they may be generated. Occasionally single diaphragms

of unusual thickness may be again ruptured, but no considerable increase in their number ever occurs after their first formation.

It is easy with the low power of the microscope to count the diaphragms in leaves floating upon a little water on a slide. The usual number is from fifty to seventy, and is quite as many in young leaves three fourths of an inch long as in leaves fully formed. It is instructive, too, as proving the absence of a definite meristematic zone, to count the average number of superficial cells which intervene between the diaphragms. In very young leaves this is from three to six or eight throughout the whole length, but in older leaves it is much greater, varying from twelve to twenty in the tip region to forty to sixty in the middle and basal regions, which remain longest in the meristematic condition.

The diaphragms, I think, are quite functionless, and their existence merely incidental to the manner of origin of the air chambers. They are too delicate to serve for mechanical support, which is sufficiently secured by the four longitudinal bands already described. The position of the air chambers and longitudinal bands between them in relation to the axis of the plant is always the same as that indicated in *figs. 10, 11, 44*. Near the ligule the air spaces are less regular, and instead of four of them symmetrically placed we find many irregular ones. Behind the sporangium the dorsal longitudinal band of living cells, and sometimes the two lateral ones, are well marked, but there are no large distinct air spaces. The vascular bundle of the leaf is as characteristic as that of the stem. My observations, referring chiefly to the changes of form of the bundle, were made with the view of discovering whether there is any definite relation between it and the sporangium or the ligule, and whether it presents any evidence that the leaf of Isoetes has been reduced from a more complex type. The leaf trace can first be recognized in the base of the young leaf and in the stem region below it towards the central bundle. The xylem elements are first differentiated, and consist of five or six tracheids grouped into a cylinder and surrounded by a sheath of parenchymatous cells with dense

contents. These parts can be traced later to the corresponding parts of the axial bundle. Behind the sporangium the xylem spreads out into a broad band in which the amount of xylem parenchyma is greatly increased, and the tracheids are in five or six scattered groups. Above the sporangium the xylem contracts again into a cylinder, and lies between the cornua of the ligule base. A more striking change occurs above the ligule where the xylem elements suffer an extreme diminution, there being in that region in *I. echinospora* only a single imperfect central tracheid surrounded by a sheath of parenchyma (*figs. 9, 10*). Occasionally in *I. echinospora*, and usually in *I. Englemanni*, two, sometimes three, other such groups can be traced up the leaf.

The phloem is best represented in the chlorophyll-bearing portion of the leaf. It there consists of two strap-shaped bands on the dorsal side, more or less united by their edges, so as partly to surround the xylem. In less distinct form the phloem may be traced downwards to the region of the central bundle.

The development of the ligule was accurately described by (Hofmeister 1), and also by Hegelmaier (1). The latter refers its origin to more than one cell. Since the former gives few figures, however, and the latter none, I shall again briefly outline the course of growth and illustrate it with a few drawings. The ligule originates from a single large vesicular cell protruding from the ventral face of the leaf rudiment. Provision for its rapid growth is shown in the large size of the nucleus of this cell, and the density of the cytoplasm (*figs. 12, 13*). The first division is always parallel to the face of the leaf (*figs. 14, 15*), and usually the second division is parallel to the first. The ligule of *I. lacustris* is described as passing through a filamentous stage; but in *I. echinospora* and *I. Engelmanni* it is hardly worth while to distinguish such a stage, for the filament never consists of more than three cells. The terminal cell then divides in a vertical plane at right angles to the first wall (*figs. 16, 18*). Other vertical divisions follow until the ligule has become a plate of cells of very regular arrangement. *Figs. 18*

and *19* are median sections of the ligule made tangentially to the face of the leaf. Longitudinal sections are shown in *figs. 26, 27, 28, 33, 35*. Growth in length and breadth continues very rapid, and the ligule soon overtops the leaf (*fig. 8*). For some time it remains a single layer of cells in thickness, but eventually it becomes double throughout most of its extent. The doubling begins in the middle region near the base and extends in all directions, never reaching the apex or margin however, which remain to the last but one layer in thickness (*fig. 21*). The expanded part soon reaches its maximum growth. Not so the foot region; this becomes quite massive and deeply embedded in the tissue of the leaf, especially at the sides which grow upward and downward into two prominent cornua. *Figs. 22–25* may help to explain the form of the base of the ligule. *Fig. 25* is a transverse section of the leaf cutting across the cornua above the main place of union of the ligular and leaf tissues. Sections below it show the cornua connected by a transverse band embedded in the leaf; and sections still lower would show portions of the cornua only. The other figures need no fuller explanation than that accompanying the plates.

Along with the growth of the ligule there comes about a differentiation of the cells composing it. There may be said to be four regions. The base is closely surrounded by a layer of small deeply-staining gland-like cells (*s* in *figs. 22, 38*) which we may call the sheath. It forms a conspicuous layer, everywhere investing the base of the ligule, and becoming continuous with the superficial cells of the leaf. Next to the sheath is an irregular layer or band of large empty cells, the *glossopodium* (*g* in *figs. 22, 38;* see also *figs. 23–25*). The glossopodium appears to form the base of the ligule, but the true base includes the sheath which, as a study of the development shows, is derived from the lowermost cell of the young ligule (*fig. 38*). Above the glossopodium are smaller cells containing protoplasm and forming the greater part of the ligule. The apex and margin of older ligules constitute the fourth region; the cells are

shrunken and contorted, their nuclei broken down, and the cytoplasm disorganized.

A study of the ligule of Isoetes to be complete must be accompanied by a comparative examination of the ligule of Selaginella. With this in view I have studied the origin and growth of the ligule in *S. Martensii* and *S. apus*, and compared my sections with the excellent drawings of Professor Harvey Gibson (2). Professor Farmer (1) has expressed the view that the ligules of Isoetes and Selaginella have little in common except their position and name. I have been led to quite the contrary conclusion, to hold in fact that there is a very close homology between the two. What has appealed most to me, in addition to the position of the organs, is the similarity of the regions of which both are seen to consist. The ligule of Selaginella has a glossopodium of large empty cells, sheathed by a gland-like layer, and shows also two upper regions, one of living and one of disorganizing cells. The two are alike also in the absence of chlorophyll, starch, and intercellular spaces; and both show their embryonic character by passing their maximum of growth before the leaf has reached its greatest functional activity. Differences are to be expected, of course, and are chiefly these: the ligule of Isoetes arises from a single cell, that of Selaginella from a group of cells; and, whereas the ligule of Isoetes is almost from the beginning a conspicuous part of the leaf, that of Selaginella is rather late in making its appearance, no trace of it being discoverable until after the sporangium rudiment is plainly perceptible.

THE SPORANGIUM.

The sporangium has repeatedly been made the object of investigation during the last fifty years. Hofmeister (1) was the first to make a careful study of its origin and development. Though his view that the sporangium can be traced back to a single cell has been discredited by later observers, I hope to show that his error was largely due to his exclusive dependence upon longitudinal sections. Except for his failure to see the true

nature of the sporangium rudiment as a transverse row of cells, his account is surprisingly accurate when the imperfect methods of sectioning and staining of that time are taken into consideration.

According to Hegelmaier (2) and Tschistiakoff (1) the sporogenous tissue is differentiated out of a considerable mass of deep-lying meristem between the epidermis and the vascular bundle.

Goebel (1) agrees substantially with the two preceding authors, but is more explicit in his description. The *Anlage* of the sporangium according to him is a group of cells of the leaf base, chiefly the three upper layers. The outer layer gives rise to the sporangium wall, and the hypodermal layer to the archesporium from which all the spore mother cells, trabeculæ, and tapetum are derived. Goebel's account, as confirmed and restated by Sadebeck (1) in Schenck's *Handbuch der Botanik*, has formed the basis of all the text-book descriptions of the sporangium of Isoetes written since that time.

The latest student in this field is Bower (5), whose description is confirmatory of Goebel's except that he traces the origin of the sporangium to a group of superficial cells. This difference, however, is of the very greatest importance. For whereas the derivation of the archesporium by periclinal divisions of superficial cells is the rule in Pteridophytes, the origin of the sporogenous tissue from a hypodermal layer separated from the beginning from the epidermis is a spermatophyte character. The result of Bower's work then is to put Isoetes in line with other Pteridophytes in respect to the origin of the archesporium.

My own results are in the main confirmatory of Bower's as to the origin of the sporangium, though with variations in minor details which may be due to specific differences (Bower studied *I. lacustris*); but as to the later stages of development, especially of the megasporangium, I cannot make my observations harmonize with any accounts hitherto written.

It will, of course, be apparent, when so many discrepancies appear in the descriptions of different investigators, that the

study must be one which involves considerable technical difficulty. This is attributable (1) to the absence of an elongated axis and internodes and the consequent crowding of the sporophylls, and (2) to the early appearance of the sporangium and the consequent difficulty of distinguishing it from the other meristematic tissues in which it is placed. The kinds of evidence on which I have relied in my interpretations may be stated briefly as follows:

1. Study was made of sporangia whose sporogenous tissue was already distinct and unmistakable. Then by comparisons with successively younger sporophylls the attempt was made to trace the sporangium to its earliest rudiment.

2. A careful comparison was made of sections in the three planes, longitudinal, transverse, and tangential. This involved the waste of a great deal of material. For it will be made clear by a glance at *fig. 4* that sections made longitudinal to the stem could give longitudinal sections of very few young leaves, and oftener than not would fail in this altogether, since the leaves have a spiral arrangement; while, in order to obtain transverse and tangential sections, one must cut obliquely to the stem without possessing any clue by which to determine the proper angle of obliquity.

3. The position of the vascular bundle enables one to determine whether the sections are truly longitudinal, and which of a number of serial longitudinal sections is exactly median. This help is available only after the sporangium is distinctly outlined, and somewhat advanced in development, for in case of very early stages of the sporangium, the vascular bundle has not yet been differentiated.

4. In such early stages one must depend very largely upon the ligule, which in position and outline is so definite, and in manner of growth so regular as to make it of the highest importance in assisting one to orient the sections.

5. The sporogenous tissue is often distinguishable from vegetative tissue by a difference in staining. There are three periods when this difference is most manifest. The superficial

cells which form the earliest rudiment of the sporangium frequently take a distinctive cytoplasmic staining, especially in material fixed in Flemming's solution. It must be confessed that this means of recognizing sporogenous tissue is not so trustworthy as one could wish, for at this period of the leaf's history all the tissues are meristematic, and hence readily susceptible to protoplasmic stains. One who studies the origin of sporangia in Lycopodium or Selaginella meets with the same difficulty in those plants, a difficulty in my experience quite as great in these cases as in Isoetes. When the superficial layer of the sporangium has assumed its character as an epidermis, the deeper lying sporogenous cells are easily distinguishable by stain reactions from the surrounding tissues. At a later period the spore mother cells selected out of the general internal mass of the sporangium become quite distinct on account of their denser contents and more intense staining.

Longitudinal sections of young leaves show no space between the base of the ligule and the stem. At this time there is still an active uplifting of cells above the general stem level, a continuance of the process by which the leaf first emerged. When the ligule has grown sufficiently to contain eight or ten cells in longitudinal section the space below it is occupied by one large cell with dense cytoplasmic contents (*fig. 26*). The next change which takes place is a transverse division of this cell as shown in *figs. 27, 28*. Comparisons of successive serial sections show that the two cells shaded in *fig. 27* form the middle of a group of cells arranged transversely to the leaf. This group of cells, distinguishable in good preparations by their deeper staining and larger nuclei, constitute the rudiment of the sporangium. In order to learn its extent and arrangement recourse must be had to transverse and tangential sections.

Most transverse sections of this early stage of the sporangium show that it is five cells in width. Whether or not these can be traced back to a still smaller number I am in doubt. *Fig. 29* certainly shows an example where the transverse row consists of only three cells, and it is clear that the shaded cells of *fig. 30*

may have had their origin in three similar to those of *fig. 29*. But I have succeeded in getting only two such cases as that of *fig. 29*, one in *I. echinospora* and one in *I. Engelmanni*, and have failed altogether to obtain a tangential view.

Tangential sections of the leaf at this early stage are almost uninterpretable. The face of the leaf is so closely pressed against the back of the next younger one that it is quite impossible in most instances to distinguish the tissues of the two leaves or to determine what is a truly tangential section. That shown in *fig. 31* was such as to admit of certain interpretation. The shaded cells occupy the surface of the leaf and clearly correspond to the group which we have already examined in longitudinal and transverse sections. It is probable that another cell seen in the adjacent section to the left of those figured belongs to the same group, making the total number of cells seven.

It is evident from a comparison of my *figs. 26–28* with *figs. 104–106* of Professor Bower's plates, that the longitudinal growth of the leaf base of *I. lacustris* is much more rapid than that of *I. echinospora;* and his figures though not his text suggest that the six superficial cells which make up the sporangium *Anlage* are derived from not more than three rows and probably from but two. If this suggestion be correct, it would bring Bower's and Hofmeister's accounts, so far as regards longitudinal sections, into harmony with each other, and with the foregoing account of *I. echinospora*.

The young sporangium, situated as it is on the hollow side of the leaf crescent, projects little if at all from the surface. By its rapid growth, however, it soon forms an oval prominence at first wider than long, then nearly circular in surface view, and finally considerably longer than wide. In its development I have not been able to establish any regular order of sequence. Starting from such a beginning as figured in *fig. 26*, it is certain that transverse and longitudinal divisions are the first to occur. Then periclinal walls appear (*fig. 30*). The middle cells of the sporangium rudiment are at first most active in dividing, not only in respect to surface growth, but in periclinal divisions also.

Sections adjacent to that represented in *fig. 31* show three or four hypodermal cells which have been cut off from the middle cells of the group and evidently belong to the same series.

There is at no time a single complete hypodermal layer which may properly be termed an archesporium. For when the middle cells have just completed their periclinal divisions the lateral cells are still undivided, and by the time the lateral cells have undergone their first periclinal division the middle of the sporangium is at least three layers deep. A very good example of this is seen in *fig. 42*, which represents the side of quite a large sporangium.

The growth of the sporangium is carried on most actively by the two or three outer layers of cells, as is evidenced by their large size and deeper staining, and the frequency with which they are found in karyokinesis. The divisions of the superficial layer are by no means limited to those in anticlinal planes, as is usually the case with the external cells of sporangia, but for a long time they continue to add to the inner mass by periclinal divisions. In the sporangium of which *fig. 39* shows a section, as many as eight or ten of the external cells were in the act of periclinal division. Even in so old a sporangium as that shown in *fig. 43* the same process is still in continuance. The cells marked with a cross have evidently been derived from the external layer. Though in older sporangia the additions so made go to form part of the sporangium wall, there can be no question that in the younger sporangia they add to the true sporogenous tissue. The bearing of this fact upon the question of what constitutes an archesporium will be considered further on.

It seems necessary to digress at this point in order to make clear some features in which the preceding account differs from what has been recorded by previous observers. Both Hegelmaier (2) and Tschistiokoff (1) assert that the wall of the sporangium is from the beginning ("von Anfang an gesondert") separated from the inner complex, and emphasize with great distinctness the deep-seated origin of the sporogenous tissue.

Goebel (1) states his approval of Hegelmaier's view, but the occasional periclinal division of the external cells does not escape his notice, though he considers it as merely adding to the thickness of the wall. Bower (5), on the other hand, observed both the superficial origin of the sporangium and the failure of the first periclinal divisions to completely delimit the archesporium.

As already stated, I do not find the outer wall separate from the sporogenous complex from the beginning. On the contrary, it is distinctly active in increasing the dimensions of the sporangium. Ultimately the superficial layer loses some of its protoplasmic contents, and assumes the appearance of an epidermis. It sometimes happens that this separation of a wall layer occurs quite early (*fig. 41*), but oftener it is not till the sporangium has come to consist of many hundred cells. Even then periclinal divisions do not entirely cease.

According to my observations there is no regularity in the arrangement of the cells within the sporangium. The discovery of this was a great surprise to me, for Goebel's statement is very explicit: "Each of the cells composing the archesporium has an independent growth," and in this he has been corroborated by Sadebeck and Farmer. Bower has not traced the history of the sporangium with any fullness; he merely states that his results are confirmatory of Goebel's and his figures certainly convey the impression that each cell of the archesporium has an independent growth. But he has made use of the same style of drawing in representing the sporangia of other genera (Lycopodium, Selaginella, Equisetum), in which no such claim is made. In view of my own observations and of Bower's drawings, it is difficult to know just how much is meant by the phrase "independent growth."

In the case of bryophyte antheridia the primary spermatogenous cells are clearly distinguishable throughout the whole development of the antheridium, although each may become divided up into a hundred or more sperm mother cells. The individuality of the original cells is marked in several ways:

their outer walls remain straight and become thicker than those which subsequently appear within them; and the incomplete separation of the derivatives of any single primary sperm cell from one another and their complete separation from those of other primary cells are shown by their dividing concurrently. I have frequently observed in the antheridia of Polytrichum, Porella, Marchantia, and Asterella that all the cells derived from one of the primary sperm cells enter into karyokinesis together, finish their division, and enter into the resting condition together, quite independently of what may be going on in the derivatives of other primary cells. In such cases it is quite proper to speak of an independent growth; for the separation and isolation of each group by thickened walls are sufficient to insure a simultaneous exposure and obedience of all the cells to the physiological stimulus which induces karyokinesis.

Are there any indications of such independent growth in the sporangium of Isoetes? I can find none, either in the arrangement of the tissues or in the presence of thickened walls which mark the boundaries of the original archesporial cells, or in the simultaneous entrance of the cells of each group into the phases of division. All the mature cell walls of a growing sporangium are of equal thickness; and in marked contrast to what is seen in the leaves there is no regularity of stratification or lining-up of the cells. I am forced to conclude that the sporangium of Isoetes (at least of *I. echinospora* and *I. Engelmanni*), just as the microsporangium of angiosperms, grows as a unit and not as a number of individual segments.

Before continuing the subject of the development of the sporangium it will be convenient to consider the formation of the velum. The velum makes its appearance very early in the history of the sporangium, almost as soon in fact as the first periclinal divisions of the superficial cells. It is formed immediately below the ligule. Hofmeister (1) says: "Of the two cells into which by a transverse septum the cell underneath the place of insertion of the ligule is divided the upper one becomes the primary cell of the velum and the lower the primary mother cell

of the sporangium." It has already been said that Hofmeister was in error because of failure to notice the lateral extension of the sporangium rudiment. Even allowing for this, however, I am not able to agree fully with his account. It appears rather that the upper tier of cells while giving rise to the velum makes some additions at the same time to the sporangium. In other words, the velum is a sterilized portion of the sporangium. Some sections seem to admit of this interpretation only, though others, such as *fig. 32*, are not unfavorable to the view that the separation of velum and sporangium proper is accomplished by the first transverse division of the sporangium rudiment.

Early stages of the velum may be seen in *figs. 32–36;* it is at this time a transverse row of slightly projecting cells. Its cells soon become comparatively empty, contrasting strongly with the young sporangium. Growth is very rapid and in an upward oblique direction; in some cases there is a tendency to a downward growth also, such as obtains among terrestrial species.

The velum reaches its full size much sooner than the sporangium, and is not affected by the changes which determine the character of the latter. The cells of the interior become large and lose their contents; those of the inner surface layer — that adjacent to the sporangium — are smaller and more regular in size and outline, and have a semi-glandular appearance. In many species of Isoetes many of the cell walls of the velum and of the leaf region adjoining the ligule become lignified and take on spiral and annular thickenings. *I. echinospora* and *I. Engelmanni* offer no exception in this respect, the thickenings being much more pronounced in the latter species. The change first appears in proximity to the ligule, and spreads thence into the remoter parts of the velum and of the leaf. The thickened cells never have any connection with the vascular bundle (*figs. 23, 24*).

FURTHER DEVELOPMENT OF THE MICROSPORANGIUM.

In origin the two kinds of sporangia are identical, and for a considerable period of their development they exhibit no

observable difference. The general statement of the text-books, following Goebel and Sadebeck, is that they follow the same course of development only so far as the formation of the archesporium, and thereafter may be distinguished by their manner of growth. It is said that in the megasporangium certain archesporial cells divide only by periclinal walls, but in the microsporangium all the archesporial cells divide both anticlinally and periclinally, and that in this respect the two are distinguishable from the archesporial stage on. Such is not the case in the forms which I have studied. In these all the archesporial cells, whether of megasporangium or microsporangium, undergo divisions in all directions, and the similarity of the two kinds of sporangia continues much beyond the archesporial stage. Not only do they agree in origin, but up to a time when they are eight or ten cells deep, they agree absolutely in manner of growth, and exhibit no histological features by which one may determine whether a given sporangium will bear microspores or megaspores.

As an example, consider the sporangium of which *fig. 43* represents a section. It had advanced so far beyond the archesporial stage as to contain about 8000 cells. From the position of its sporophyll we may infer it was destined to become a megasporangium. But there is nothing in the arrangement or character of the cells or in their mode of division to warrant that prediction, or to enable us to say such a group of cells will become a trabecula, and such a group will produce spores. It has the characters neither of a megasporangium nor of a microsporangium, but is as yet quite undifferentiated.

The first changes which occur to mark the microsporangium are those which lead to the differentiation of the spore mother cells from the trabeculæ, sporangium wall, and tapetum. Previously there has been no essential difference in the cells as to size, form, or contents, excepting the external layer. But when the sporangium is approaching a limit of cell multiplication, that is, when the number of cells is 15,000–20,000, certain regions begin to lose their power of division and reaction to stains, while

other regions become more active in division and more deeply stainable. The former may be called the sterile regions, since they form the walls, trabeculæ, and tapetum, and the latter the fertile region, since they give rise to the spores. Even in unstained sections the difference is noticeable as one of relative abundance of protoplasmic contents.

At first it is difficult to see clearly the limits of the regions or to make out their arrangement. But in older sporangia they are seen to be disposed in irregular bands extending from the base of the sporangium outwards to the wall. The published drawings, and unfortunately in some cases the written description also, are calculated to convey an erroneous idea of the trabeculæ. They are not partitions, but, though irregular in outline and frequently branched and anastomosed, are comparable rather to pillars. It is accordingly incorrect to speak of the sporangium as chambered, for the fertile cells are not segregated into loculi, but form a continuous mass pierced here and there by the trabeculæ. It is hoped that *figs. 44–47* will make the relations of the trabeculæ clear. The shaded portions of these drawings represent the fertile regions, and the unshaded portions the trabeculæ and walls. The continuity of the sporogenous mass is clearly seen in the tangential section (*fig. 46*).

A more detailed account of the development of the microsporangium will now be given. *Fig. 48* shows a small portion of a microsporangium in which the differentiation into sterile and fertile regions has just begun. The fertile cells stain deeply and are still rapidly multiplying, as is evidenced by the many karyokinetic figures. The sterile cells have almost entirely ceased divisions, though here and there a dividing cell may be found. It is important to notice that the one character in which the two regions differ is in the relative abundance of protoplasm, the fertile cells being densely filled with deeply staining cytoplasm, while the cytoplasm of the sterile cells is beautifully vacuolated. In all other respects the cells of the two regions are essentially alike. They are not markedly different in size,

or in the size and appearance of their nuclei, nor is there anything in their arrangement to suggest a difference in their origin or growth. In fact, as Professor Bower has pointed out, there is here a most excellent illustration of the sterilization of sporogenous tissue.

The trabeculæ at this age show about 15–25 cells in cross-section (tangential section of the sporangium), and are more or less cylindrical. There is as yet no tapetum. Towards the outer and inner sides of the sporangium the trabeculæ are continuous with about three layers of cells which form the sporangium wall (*fig. 49*). That the trabeculæ and walls are of the same nature, both being the result of sterilization of potentially sporogenous tissue, is proved not only by the similarity of their cells, and their passing uninterruptedly into one another, but also by their relation to the tapetum, which is formed out of the layer that lies next to the spore mother cells.

The inner cells of the trabeculæ, those which become the trabeculæ proper (*i. e.*, exclusive of the tapetum), are at first isodiametric and in no way different from the outer ones. But while the latter are undergoing a transformation into tapetum, the former undergo changes which are dependent on the growth of the sporangium. As the dimensions of the sporangium increase — a change which goes on rapidly at the period when the sporogenous cells are multiplying — the trabeculæ are necessarily lengthened. This is accomplished, not by division of the cells, but merely by their elongation. At the same time they suffer a lateral compression from the growing sporogenous cells and become flattened (*fig. 50*). The tabular form of the cells doubtless furnishes the ground for the common view, which ascribes the form of the cells to the direction of their division planes. Such a view is incorrect, however, for divisions have entirely ceased in this region before the elongated form of the cells is attained. The shape of the cells is easily accounted for by their growth in the one direction possible for them while yielding to the pressure of the turgescent mother cells.

In this connection it may be remarked that with the possible exception of the tapetum all the cells of the sporangium, after

losing their power of division, enter upon a period of growth which is quite comparable to that occurring in vegetative meristems. The difference in size of the sporangia represented by *figs. 43* and *63*, which are drawn under the same magnification, is due partly, it is true, to increase of the number of cells, but a glance at the two figures shows there has been also a decided growth of the individual cells.

Accompanying the modification of the trabecular cells, there is a change of form of their nuclei. These become first elongated and oval (*fig. 50*), and finally spindle-shaped, suggestive of the changes which attend the development of the vascular strand out of the tissues of a growing point. Instances of much greater elongation than that shown in *fig. 51* are frequently met with, though in other cases the changes are comparatively slight. The nuclei at this time are relatively large and prominent, and appear to form the center of aggregation of what little cytoplasm still remains in the trabecular cells. In old sporangia the cells of the trabeculæ are nearly or quite empty, and much compressed.

Bower has discussed the function of the trabeculæ. They may serve for mechanical support of the sporangium, or to afford a larger nutritive surface, or, since the two functions are not incompatible, for both. The relation of the trabeculæ to the base of the sporangium where it is closest to the vascular bundle, and the resemblance of the nuclei to those of plerome regions in general, suggested to me that the trabeculæ might be the channels through which nutriment is supplied to the spores; but the suggestion is not borne out by observation. It is clear that in a hydrophytic plant no elaborate apparatus is needed to provide the sporangium with water, which can easily enter directly from the outside; and an examination of my sections shows that the organized food stuffs, such as starch and oil, pass to the spores through the inner wall of the sporangium, and not through the trabeculæ.

The tapetum, as already stated, is organized out of that layer of the sterile cells, whether of wall or trabeculæ, which is in contact with the fertile cells. At a stage between those shown in *figs. 48*

and *50*, the cells of this layer multiply rapidly. They are frequently found in mitotic division, with the axis of the spindle always perpendicular to the surface of the trabeculæ or sporangium wall. Divisions may still go on here after the spore mother cells have reached maturity, and the changes of the trabeculæ are nearly complete. In this way the tapetal cells become very numerous, but reduced in size. They form but a single layer except in limited areas, where a doubling may sometimes occur.

At first the tapetum is not deeply stained (*fig. 50*), but as the spore mother cells prepare for their tetrad division, the tapetal contents increase in density, and they continue to do so until they surpass young spores in this respect.

From what has been said, and from *figs. 47*, etc., it will be understood that the tapetum completely invests the trabeculæ and sporangium wall, forming a lining layer everywhere between the spore mother cells and the sterile regions. It is a persistent layer, and in this respect is to be contrasted with that of most ferns and angiosperms. In these latter the walls of the tapetum break down and are dissolved, the cells become disorganized, and their materials, mingling with the other contents of the sporangium, are used to nourish the mother cells or young spores. In Isoetes, however, as in Lycopodium and Selaginella, no such disorganization of the tapetum occurs. Its cells do not fall apart and its walls are not absorbed. In old sporangia it is still recognizable, though often its contents have been lost and the walls are pushed nearly together.

Probably the tapetum can best be regarded as a gland or layer of glandular cells. If so, the manner of action in a persistent tapetum, such as that of Isoetes, Lycopodium, and Selaginella, must be quite different from what it is in a tapetum which is regularly disorganized and absorbed. In the one case the nutrient substances secreted by the cells must be passed on through the walls into the cavity in which the young cells are growing. In the other case there can be little or no passing of nutrient substances through the walls, but at the proper time the

secreted materials are rendered available by the total collapse of the cells.

In many plants also, especially in those in which the tapetum undergoes complete disorganization, it is common for the tapetal cells to become multinucleate, the division of the nuclei being sometimes accomplished by karyokinesis, but mostly by amitosis. The cells of the tapetum of Isoetes, in this respect again agreeing with Lycopodium and Selaginella, are uniformly uninucleate.

In almost every sporangium examined the number of layers of cells outside the fertile regions when they first become distinct is three. In a very few cases there were four layers. As already shown, the innermost of these becomes tapetum. Of the other two layers, one, apparently the hypodermal, usually undergoes division, so that the wall region ultimately consists of three layers outside the tapetum.

At the base of the sporangium, between it and the vascular bundle, are a few layers of cells which may be regarded as the inner wall of the sporangium. The exact origin of these I have not been able to make out. Whether, like the outer wall, they are derived from the sterilization of sporogenous tissue, or whether they are derived from the tissues underlying the original archesporium, I cannot say. It is always difficult in all sporangia except the very youngest to define the exact inner limits. Between the vascular bundle and the three or four outer layers where growth and division are most actively carried on, there is a mass of small cells staining deeply. Such a section as *fig. 38* makes it probable that all the tissues between the parenchymatous sheath of the xylem and the outside arises from the sporangium *Anlage*, and that therefore the inner wall arises also by sterilization.

The formation of the microspores in Isoetes takes place in much the same way as in other vascular plants. After the fertile regions have ceased their cell divisions, the cells and their nuclei pass through a period of rest and enlargement. The nuclei especially increase in size and become rich in chromatin. At the same time the cytoplasm remains dense and never

shows the vacuolated appearance of the sterile cells. Shortly afterwards the mother cells break away from the tapetum, which from this time on gains in density and apparent activity. The mother cells, at first in a continuous mass, soon break up into smaller and smaller groups of cells by the enlargement of the cavity in which they float. Finally the individual cells fall apart and round up, and pass rapidly through the two divisions by which the microspores are formed.

No attempt was made to follow closely the cytology of these divisions because it was found impossible to make any satisfactory observations on the corresponding divisions of the megaspore mother cells. The following notes may however be of interest. The achromatic figures appear to have a polycentric origin, and the chromatin passes through a synapsis stage. All the nuclei make their preparation for division and begin to divide almost simultaneously, and this notwithstanding their immense number. It is possible to find a better series of karyokinetic figures in a single sporangium of many ferns, where there are but sixteen mother cells, than in an Isoetes microsporangium where the mother cells number three or four times as many thousand. This I think may be regarded as an additional proof of the growth of the sporangium as a unit, and not as an aggregation of segments.

In the majority of cases the two divisions are of the type which is characteristic of cycads and monocotyledons, and has been called "successive;" that is, the first division of the nucleus is followed by the formation of a cell wall before the immediately following division of the daughter nuclei (*fig. 53*). The spores in this case are bilateral and may have their nuclei in one plane or in two planes at right angles to each other. But it is not at all infrequent to find the divisions of the simultaneous type; that is, the first division of the nucleus is not attended by cell division, but before a wall is formed between the daughter cells each new nucleus begins its second division (*fig. 54*). In this case the spores may be of the bilateral type, as in *fig. 55 a* and *b*, or they may be tetrahedral as in *fig. 55 c*. Much

diversity may be found within a single sporangium. *Figs. 53 a, b, c,* and *54 a, b, c,* were all taken from the same section of the same sporangium. Probably the variation in this respect is not of great importance except as indicating that the divisions of Isoetes have not acquired so definite and settled a character as those of most other plants.

Although the nuclei of the young spores may arrange themselves in typical tetrahedral fashion, there is an important difference between their relation here and in the tetrahedral divisions of dicotyledons, Lycopodium, etc. In these it is well known that all four nuclei (of such a stage as *fig. 54*) become connected by spindle fibers, and that the walls separating the spores are formed in connection with the thickening of the cell plates of the six spindles. In spite of careful search I have been unable to find in Isoetes any such sextuple spindles. The daughter nuclei are connected only in pairs, as in *fig. 53* or *54*. In what way the spore walls originate in such cases I cannot conjecture. It seems certain they are not formed in connection with the achromatic figures, unless it is possible that the cell plate, which is always present in the first division, may make its influence felt later on, and ultimately serve as the basis of the wall.

The young tetrads soon fall apart, and the individual spores lose their angularity and round up, still retaining traces, however, of the bilateral shape impressed upon them by their manner of origin. When once the permanent form is assumed there is little further increase of size. The mature spores of *fig. 56* are little larger, it will be seen, than the newly formed spores of *fig. 51*.

An interesting phenomenon in connection with the microspores is the extreme smallness of their nuclei in comparison with those of the mother cells. One would naturally expect the relative volumes to be about 1 : 4, or the relative diameters to be about 3 : 5 (since $\sqrt[3]{\frac{1}{4}} = \frac{3}{5}$ nearly). But the volume of the microspore nucleus is really no more than one twelfth of this estimate; or to express the comparison in another way, it would need the nuclei of fifty microspores combined to equal the

volume of one mother cell nucleus. Very likely similar reductions in the volume of the microspore nuclei occur during the tetrad division of other plants, but I have not seen any other case where the disparity of size is so great, nor do I remember to have read any record of such a reduction.

The number of spores formed within a microsporangium is enormous — much greater than in any other living plant. In some species it is said to exceed a million. But the largest number I have found in *I. echinospora* is 300,000. My estimates place the average number from 150,000 to 250,000.

As is well known, no provision is made for the dehiscence of the sporangium wall. The spores are set free only by the decay of the tissues enclosing them.

FURTHER DEVELOPMENT OF THE MEGASPORANGIUM.

My observations on the development of the megasporangium differ very much from those of previous investigators, so very much, indeed, that I would be loath to present them at all had I not confirmed them again and again by long and careful study. These differences are concerned not only with the origin of the archesporium and early growth of the sporangium, which have been already spoken of, but they involve also the manner of selection of the mother cells and the origin and behavior of the tapetum. A discussion of the points at issue will be reserved until the general history of the megasporangium has been considered.

One of the first megasporangia which I sectioned presented the appearance shown diagrammatically in *fig. 67*. The two large cells *M* and *M* are evidently megaspore mother cells, but what is the group of cells *a*, corresponding to them in outline and position? It consists of six cells in all, three in the section under examination, and three others in the adjacent section. A little search discovered other similar groups of a variable number of cells, sometimes but two or three, often five or six. If the number had been constantly four the groups might have been regarded as spores resulting from a precocious division of

the mother cells. But that explanation being precluded it became necessary to determine their relation to the single large mother cells, and to learn their later and earlier history. In attempting to do so I have become convinced that a very large number of cells are potentially megaspore mother cells, that a considerable number of these make a start to differentiate themselves fully from the sterile cells, but that comparatively few are finally successful in reaching the large size and well-nourished condition necessary for the production of megaspores.

The changes which first distinguish the megasporangium occur relatively earlier than those which mark the microsporangium. In the latter, as we have seen, the first change is the separation of certain sterile regions from the fertile cells as indicated by a difference in cell contents. In the former, however, changes occur at a considerable time before there is any possibility of distinguishing the trabeculæ. When the megasporangium has reached a stage of development considerably more advanced than that shown in *fig. 43*, a change is discernible in many of the cells which form the third and fourth layers approximately. The whole sporangium has at this time entered upon the period of enlargement due to the growth of the individual cells. But in *fig. 63* it is clear that certain cells have greatly outgrown their fellows. Their well-nourished condition is attested by the density of their cytoplasm and their large nuclei, which contain many nucleoli. All these enlarged cells are engaged in the struggle to become mother cells. Which and how many will be successful will probably depend upon their holding an advantageous position with respect to the supply of nutriment, perhaps also to their having obtained an earlier start.

It does not always happen that a considerable group of cells enlarge together. Indeed, it is a comparatively rare case when all the cells of the third and fourth layers enlarge to any considerable extent. Sometimes the enlarging cells are in more or less isolated groups separated by cells of ordinary size. *Fig. 64* shows such a group of cells, taken from the side of a sporangium.

Quite often, too, it happens that one cell gets the advantage almost from the beginning. But it may be stated as the rule that there is a selection and partial enlargement of many more cells than can ultimately become mother cells, and these enlarging cells belong mostly to the third and fourth layers of the sporangium, either extending continuously across the sporangium or occurring in groups separated by ordinary cells. That this condition is associated with the selection of megaspore mother cells is proved, I think, by the fact that enlarging cells, comparable to those of *fig. 63*, are never found in the sporangia formed late in the season, that is, in those which are to bear microspores.

What becomes of the defeated cells? This is a difficult question to answer, for since there is so much variation in the early condition of the megasporangium it is impossible when examining one of the later stages to tell just what the antecedent conditions in that sporangium may have been. From the frequency with which karyokinetic figures appear in the cells surrounding the nearly mature megaspore mother cells, it seems pretty certain that the cells which have been left behind in the struggle simply divide until their products have the general size and appearance of the other cells of the sporangium. If the enlargement has not gone very far the cells retain their angular configuration; if it has gone further the cells may round up while exerting a considerable pressure on those adjacent. So I interpret the group *c* in *fig. 67*.

Fig. 66 will furnish a good illustration of the behavior of the unsuccessful mother cells, although no single section can be so convincing as a series of them. The tissues are somewhat contracted, but this defect does not hide the rounded form of certain groups of cells, and their marked resemblance, except in being multicellular, to the mother cells. The section contains but one fertile mother cell, the one labeled *m*. One other is situated in the opposite end of the sporangium, just beyond the limit of the figure. The cell *a* is undergoing division, the mitotic figure being seen in the adjacent section. An interesting fact

which goes far to explain the division of the groups *b*, *b*, is the occurrence in adjacent sections of larger undivided cells (fertile mother cells), similar to *m*, and so situated as to be almost or quite in contact with the dividing groups. Their proximity accounts for the failure of the groups *b*, *b*, to produce spores. Some of the smaller and less rounded groups probably represent mother cells which suffered an early defeat, while the larger groups represent those which held out almost to the last. Such cases as these, which can be easily duplicated in rapidly growing sporangia of the right age, are conclusive, it seems to me, when considered in conjunction with the manner of growth of the sporangium, to show that the fertile mother cells are selected by their advantageous environment and not by any strict morphological position.

The fertile mother cells increase enormously in size before dividing into spores. Their nuclei maintain a proportionate growth, and their cytoplasm remains dense though not homogeneous, and frequently contains grains of starchy matter and drops of oil.

Notwithstanding the large size of the mother cells and of their nuclei I was unable to make any detailed study of their division. About the time when division occurs, the cells seem to be peculiarly liable to suffer plasmolysis, for under the action of the fixing agent they are contracted to a mere fraction of their proper volume. When sectioned in this condition they are seen to lie free in large cavities which presumably they filled completely when living, and they stain so intensely that it is impossible to make out any details of the karyokinetic process. I have not once had the good fortune to see karyokinesis in an uncontracted megaspore mother cell, although the corresponding phase of the microsporangium offers no technical obstructions to cytological study. The liability of the megaspore mother cells to suffer contraction in the process of fixation was noticed by Kienitz-Gerloff (1) and other investigators; it is possibly associated with the entrance of the nuclei into the synapsis stage.

The young megaspores almost invariably have the tetrahedral arrangement, as in *fig. 59*. Occasionally the bilateral arrangement is found, in which case the divisions so far as observed are successive (*figs. 60, 61*).

The further growth of the megaspores, the manner in which their walls are laid down, and the storing of reserve material, were not investigated.

The arrangement and subsequent development of the trabeculæ and tapetum of the megasporangium offer, as is to be expected, a rather close homology to what is seen in the microsporangium. The trabeculæ are formed out of the same kind of cells as compose all the other parts of the young sporangium. I do not discover any grounds for considering them the product of a peculiar kind of growth. They are altogether unrecognizable in the young sporangium, and their position when first outlined seems to be determined by that of the mother cells. Not until these have been selected and considerably enlarged is it possible to distinguish the trabeculæ, which then appear as feebly-staining bands extending from front to back across the sporangium midway between the fertile cells.

The cells of the trabeculæ proper undergo the same process of elongation and flattening, attended by elongation of their nuclei, that has been described as occurring in the microsporangium. The only noticeable difference is that in the megasporangium the trabeculæ are relatively fewer in number and more massive. For example, in one case, an exceptional one, I counted 400 cells in a cross section of a trabecula, whereas in a microsporangium the number of cells in a cross section of a trabecula rarely exceed fifty, and is oftener under twenty-five. This is only another way of saying that the process of steriliza tion has gone much further in the megasporangium than in the microsporangium. The total mass of the megaspore mother cell in a sporangium is only a small fraction of that of the combined microspore mother cells, though doubtless the total volume of the mature spores in the two cases is about equal.

The tapetum is formed in this case also out of those layers of the sterile cells which border upon the fertile cells. No doubt a considerable part of it is derived from the unsuccessful mother cells; but as these are the homologues of the trabecular cells of the microsporangium, being merely sterile sporogenous cells, the homology of tapetum and trabeculæ in the two sporangia is complete. The only difference which it is necessary to notice is the greater abundance of the tapetum in the megasporangium. Instead of being a single layer it is several layers in thickness (*figs. 57, 58*), and often projects into the sporangial cavity in the form of irregular papillæ, especially from the base of the sporangium. A rounding up of the cells immediately about the megaspore mother cells, such as is described and figured by Goebel, I was never able to find.

Though the megaspore mother cells do not lie in contact with one another as the microspore mother cells do, but are isolated in groups of one or sometimes two, the cavities in which they lie become continuous in the older sporangia. This is brought about by a very great enlargement of the cavities after the formation of the spores. The enlargement seems to be due to turgescence, induced probably by the osmotic activity of the substances surrounding the spores. It cannot be accounted for by mere growth of the wall cells, nor by that of the young spores, for these do not completely fill the cavities. I have computed the enlargement of the megasporangium after all cell divisions have ceased to amount to an increase of three or four times in volume. A similar change of size, though less in extent, occurs in the microsporangium.

If the preceding account of the development of the sporangia, especially of the megasporangia, be compared with the account given by Goebel (1) and Sadebeck (1), it will be seen that the differences are considerable, and of much theoretical importance. According to these writers certain cells of the archesporium divide only by the periclinal walls which serve to cut off the primary tapetal cells. In these no anticlinal divisions occur. One cell of each of the rows formed in this manner,

apparently the innermost one, though that point is not made clear in the descriptions, becomes the megaspore mother cell.[1] In certain other archesporial cells divisions take place in all planes, but more particularly in the anticlinal direction. The products of these latter cells give rise to the trabeculæ. Vines in his text-book gives nearly the same description, but says that the archesporial cell from which the megaspore mother cell arises undergoes but a single division.

If the assertion be correct that certain archesporial cells develop only into trabeculæ and certain others only into mother cells and tapetum, it is clear that there must be two categories of archesporial cells, one set destined to become sterile, the other to become fertile; and these, although indistinguishable in appearance and size, are quite unlike in their mode of division and growth and in the ultimate fate of their derivatives. It is impossible, too, to escape the inference that the megaspore mother cells are already determined in position and number when the sporangium has got no further in its development than to the differentiation of an archesporium. Further, the sporangium must be regarded as compound, each fertile archesporial cell representing a separate sporangium, and each sterile one an imperfect wall. These conclusions, which I think are logical and necessary deductions from Goebel's description, are all inconsistent with the development of the sporangium as I have found it in *I. echinospora*.

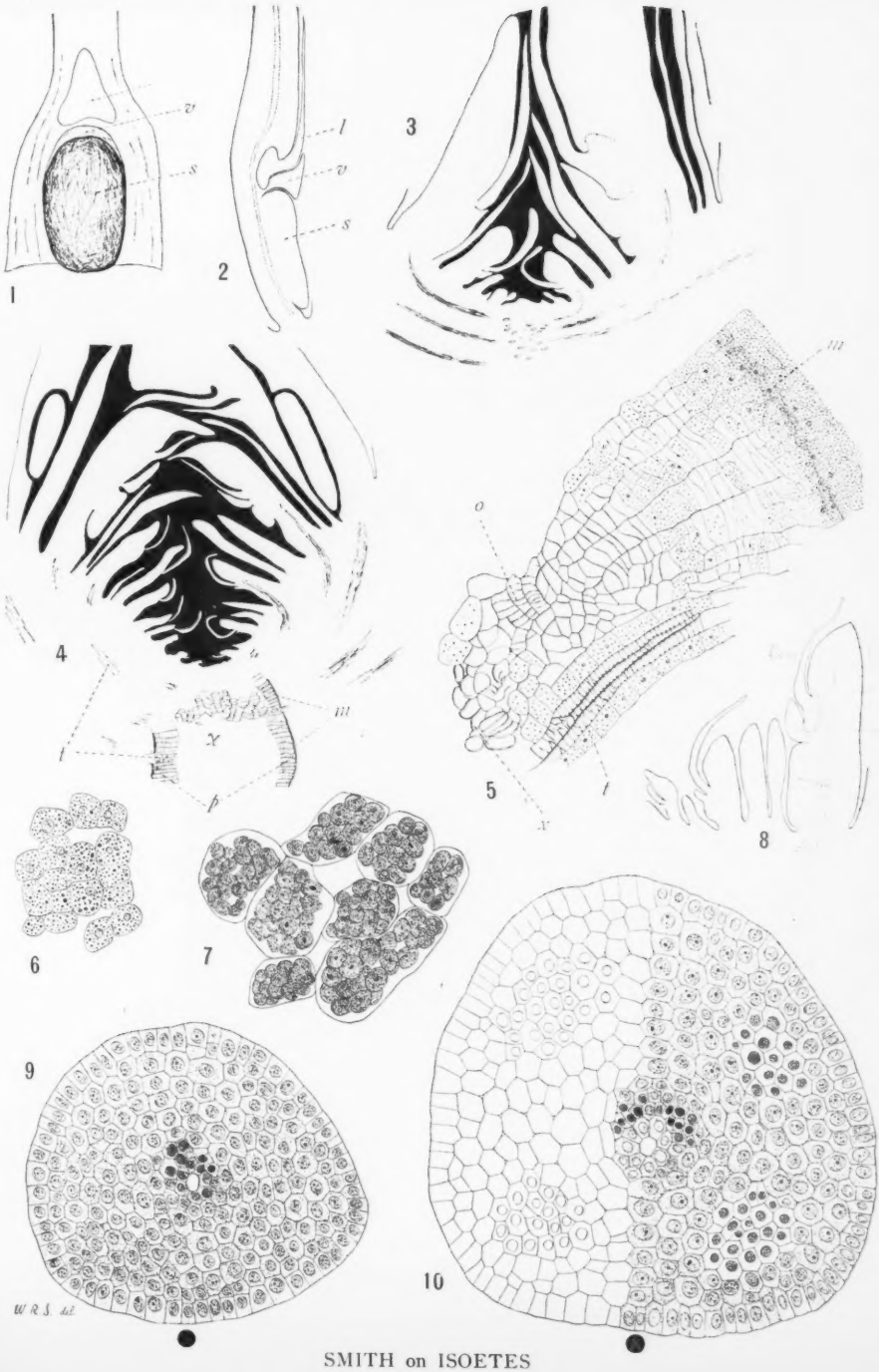
In order to bring out the points of contrast more clearly I will summarize them. I do not find any difference among the archesporial cells either in manner of development or of growth. I find no flattened tapetal cells overlying the megaspore mother cells. I find no grounds whatever for the assertion that each archesporial cell follows an independent growth, or that each megaspore mother cell represents one archesporial cell. I do not even find a single definite hypodermal archesporium which can stand as the starting point of the inferences above enumerated. On the other hand, I find the derivatives of all

[1] See, however, SCHENCK's Handbuch **3**: 392.

the archesporial cells dividing in various planes, and blending indistinguishably. The sporangium is single, not multiple, and the megaspore mother cells are not morphologically predetermined but are physiologically selected from among a large number of potentially sporogenous cells.

Though the certainty of the matter must depend upon observation, it may be pointed out that the number of megaspores has a bearing upon the question. A megasporangium contains from 150 to 250 megaspores. If we take 200 as the average, it represents fifty mother cells, that is, according to the current view, fifty archesporial cells. To this we must add at least fifty others for the trabeculæ, giving a total of one hundred archesporial cells. It does not need a very careful examination of *I. echinospora* to demonstrate the impossibility of there being so large an archesporium, for when the sporangium has a superficies of one hundred cells it is far past the archesporial stage. It is, I think, absolutely certain that each archesporial cell gives rise to several megaspore mother cells, as well as to trabeculæ and tapetum. In the microsporangium, too, the trabeculæ alone outnumber the archesporial cells (*cf. figs. 31, 46*); and their extreme irregularity and frequent branching and anastomosis make their origin each from a single cell exceedingly improbable.

[*To be concluded.*]



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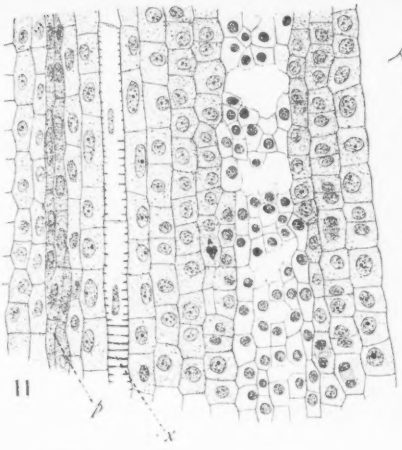

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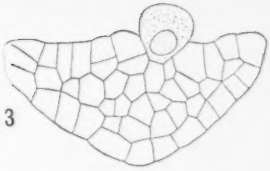

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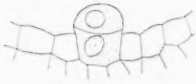

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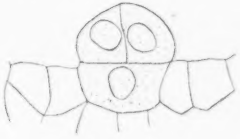

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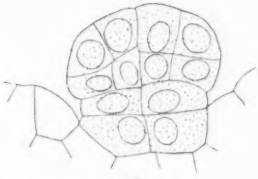

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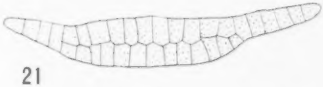

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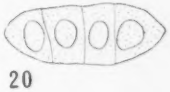

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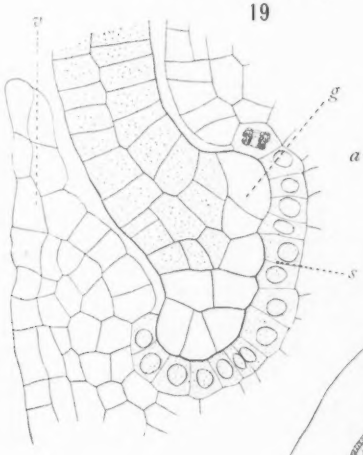

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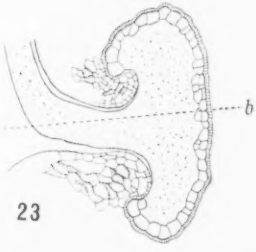

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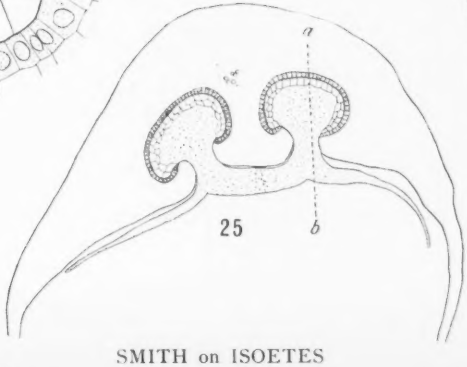

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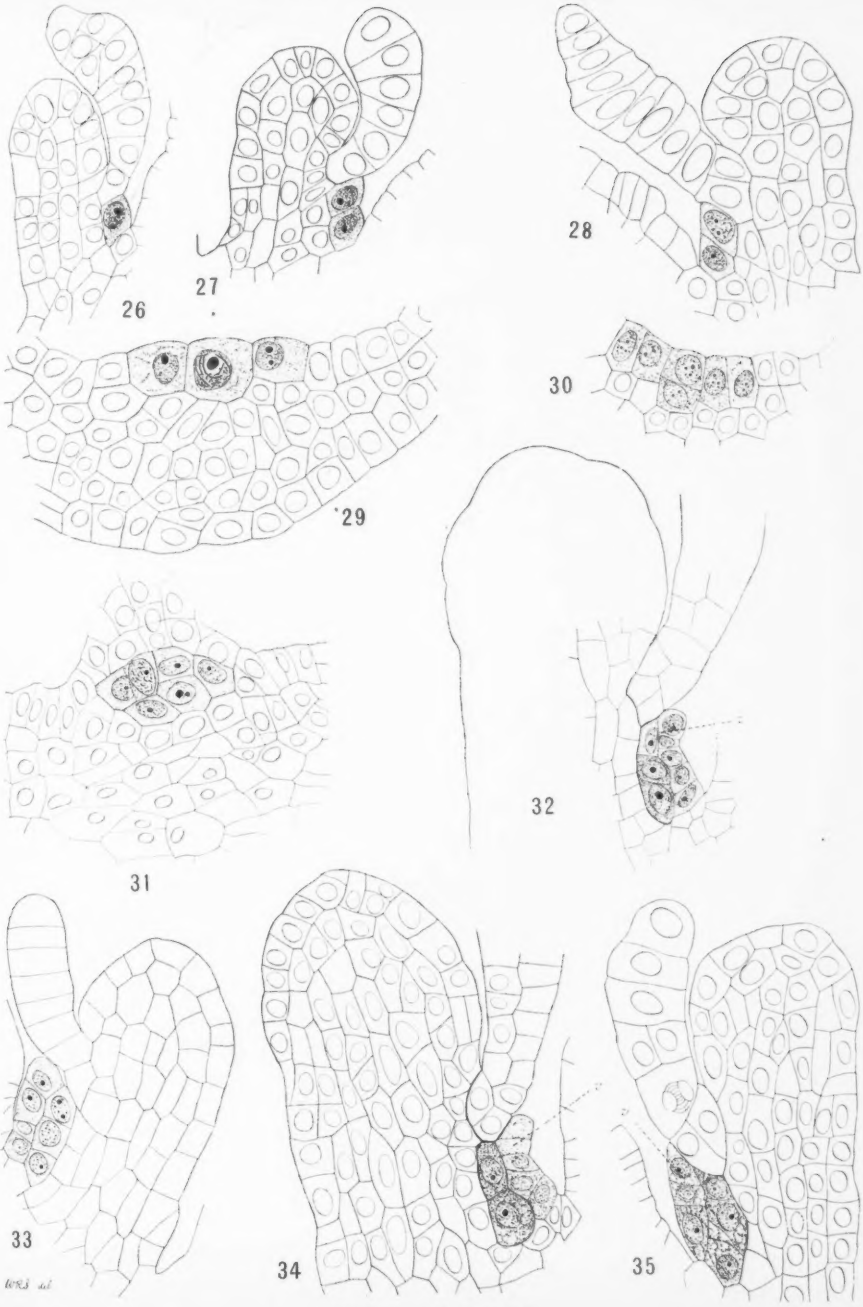

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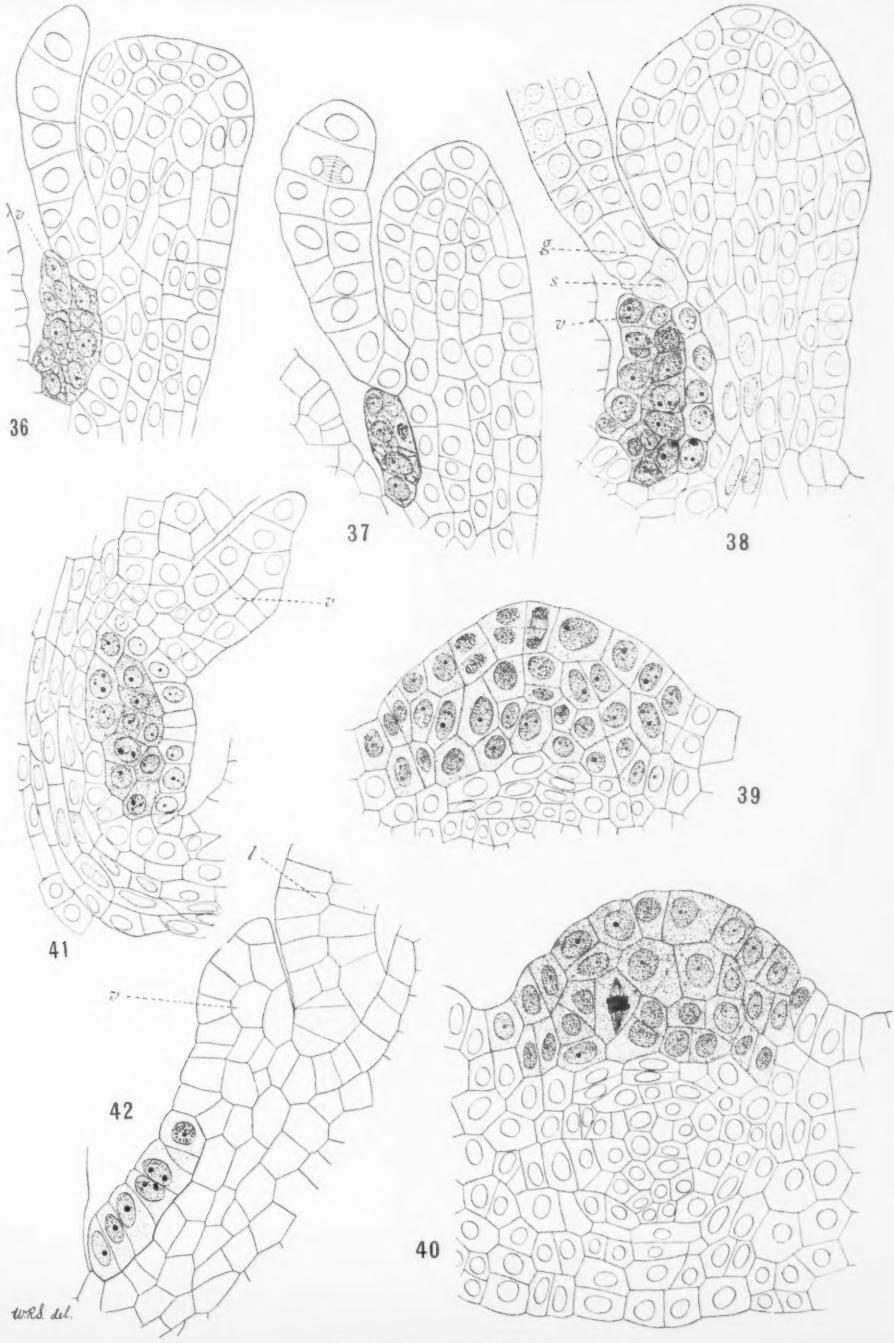

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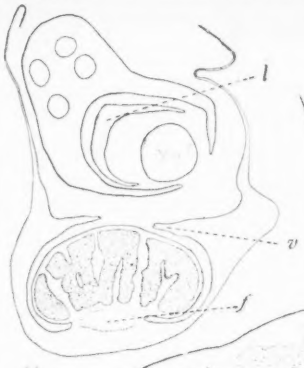

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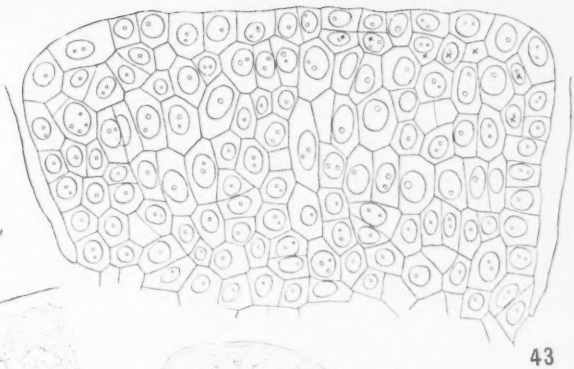

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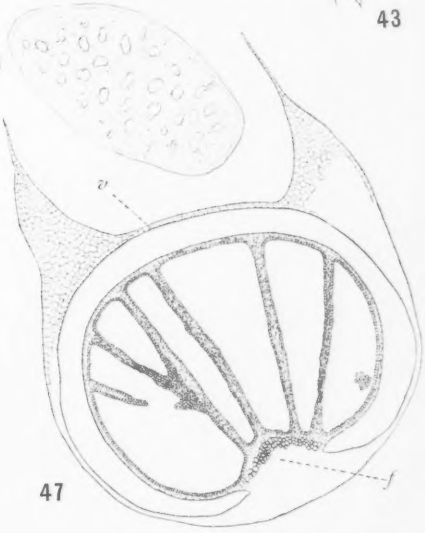

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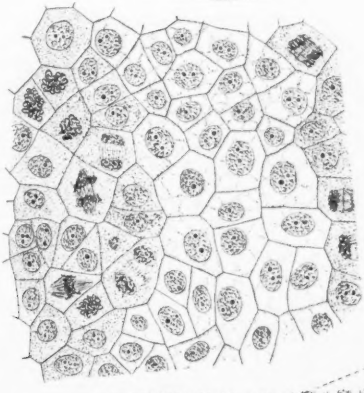

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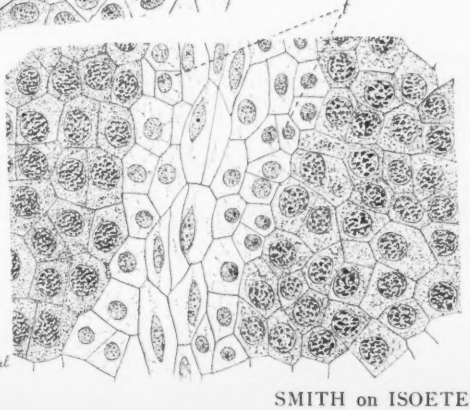

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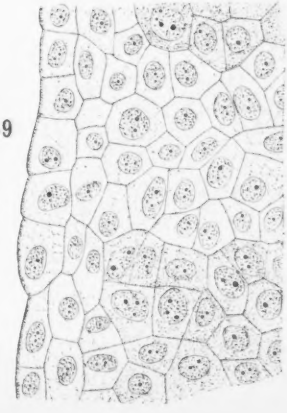

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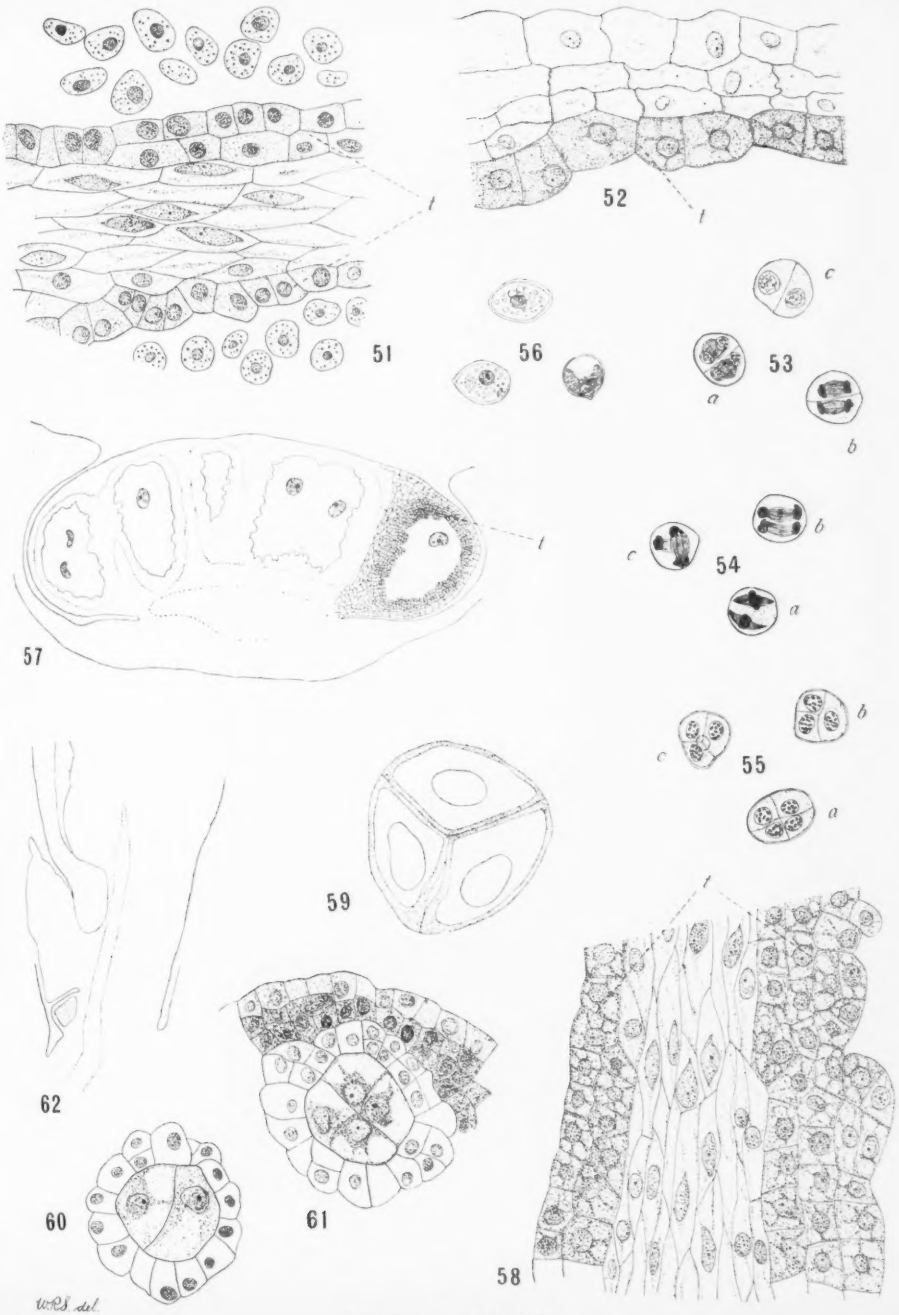

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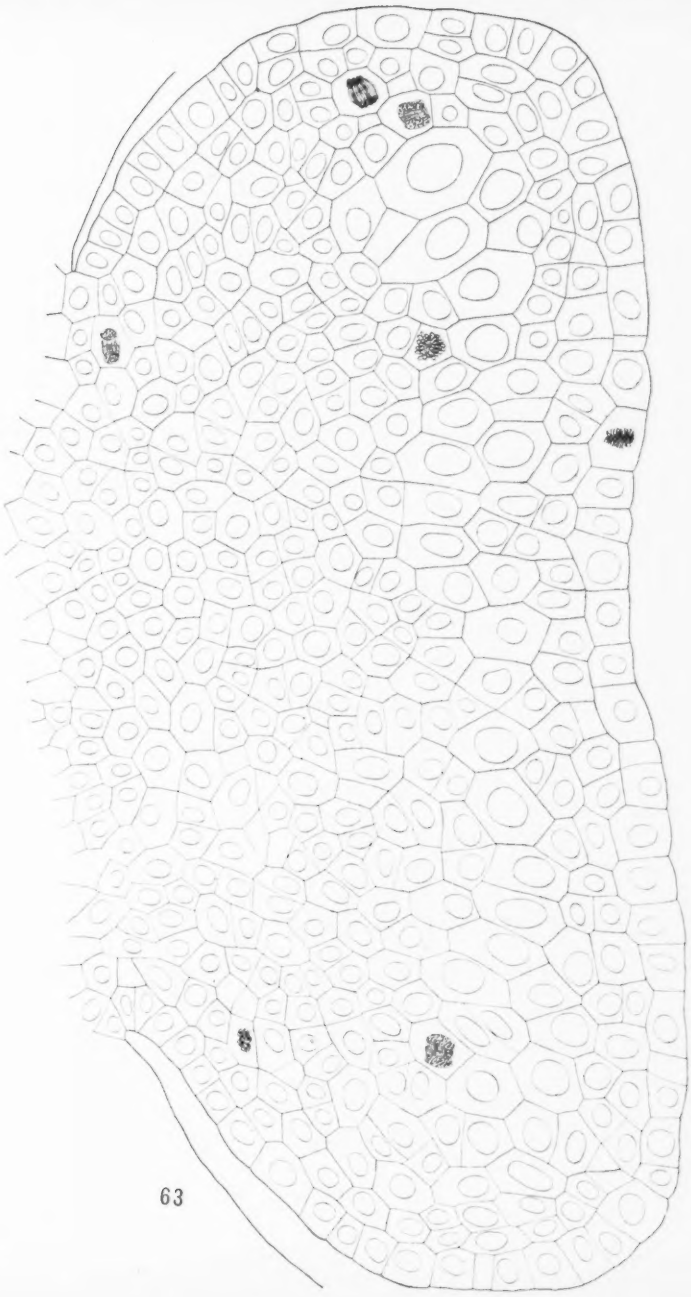

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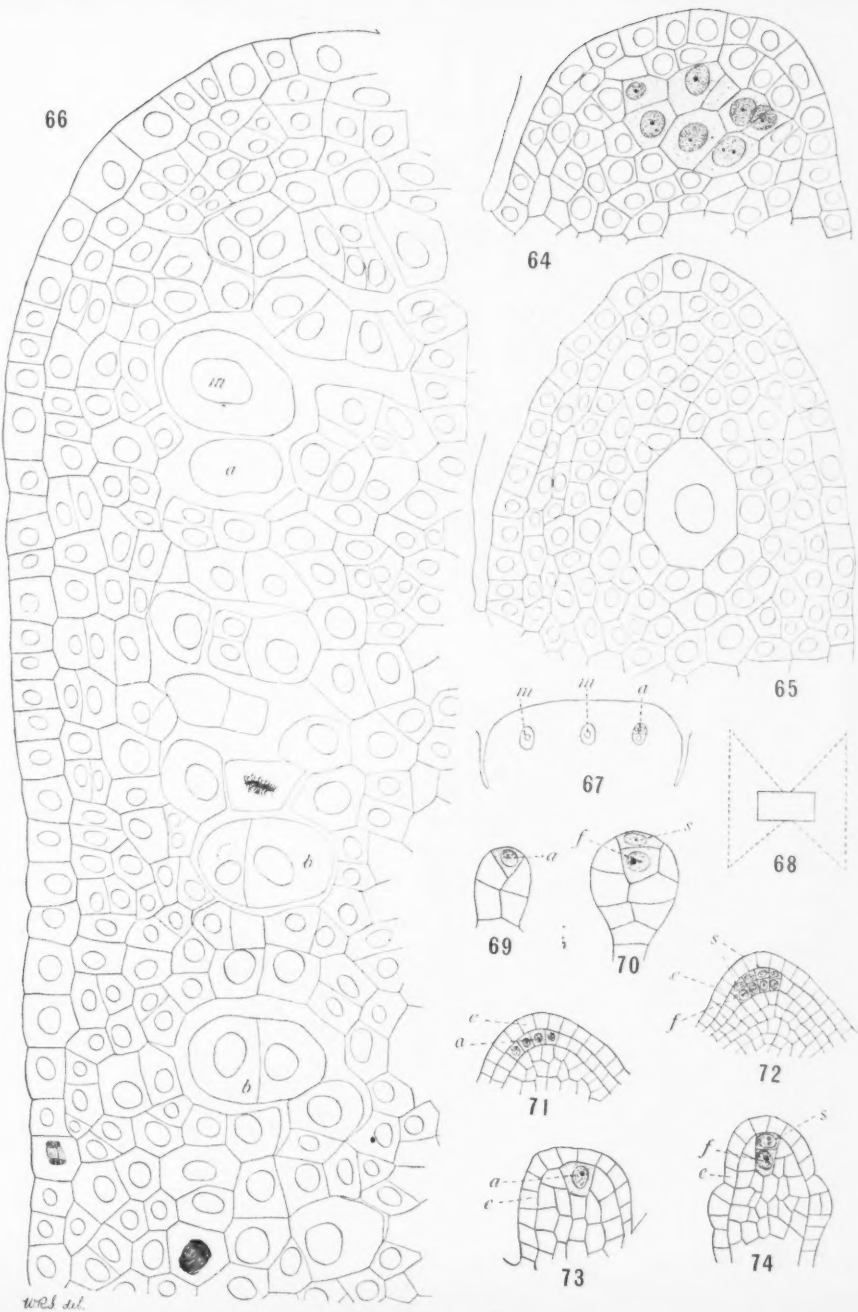

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CONTRIBUTION FROM THE CRYPTOGAMIC LABORATORY OF HARVARD UNIVERSITY. XLIII.

NOTE ON THE STRUCTURE AND REPRODUCTION OF COMPSOPOGON.[1]

ROLAND THAXTER.

(WITH PLATE XXI)

THE genus *Compsopogon* Mont., which is the sole representative of the Compsopogonaceæ, includes a few described species of filamentous algæ inhabiting the warmer regions of the earth, which are distinguished in general by their characteristic bluish or violet-green color, recalling that of some of the Myxophyceæ; while they are structurally peculiar from the fact that their filaments consist of an axial row of very large cells surrounded by one or more layers of corticating cells, the resultant structure closely resembling that of Ceramium among the Florideæ, though originating in a very different fashion.

The reproduction of these plants, although it has been very accurately interpreted by Schmitz (Engler & Prantl, Die nat. Pflanzenf., Algæ, p. 318) from an examination of dead material, has never so far as I am aware been directly observed, and since during a recent botanizing expedition in Florida I had an opportunity to study an abundance of fresh material, a special effort was made to obtain definite information on this point.

This alga was first met with at Cocoanut Grove in November 1897 along the shores of Biscayne Bay, growing most abundantly beside the road to Miami just north of the village, in ditches fed by bubbling springs which doubtless originating in the Everglades and traversing the narrow intervening strip of coral rock formation emerge in all directions along the bay and even mingle with the salt water at some distance from the shore.

[1] The substance of this Note was read at the New Haven meeting of the Society for Plant Morphology and Physiology, December 27, 1899.

The water along the margins of the bay is consequently in many places largely diluted in this way, so that, although the ditches above mentioned were repeatedly covered by the high tides during my stay, the water they contained was seldom perceptibly brackish.

A second locality was found at Daytona, a more northern station on the Halifax "river," where the alga occurs abundantly quite above and beyond any tidal influence in the rapidly flowing waters of the "canals," several of which intersect the town toward the south at right angles to the shores of the "river." A large mass was also found floating in a stagnant ditch on the Port Orange road south of Daytona, and it was seen to be conspicuously abundant in a brook which crosses the railroad just north of the New Smyrna station; while lastly a quantity was found on the margin of the St. John's river just below Jacksonville. In this connection it may be mentioned that specimens in the Herbarium at Harvard sent by Mrs. Curtiss are said to have been found in "tidal water" in the Hillsborough river near Tampa in west Florida; while it is further reported from Greencove and Blue Springs in the St. John's river region, as well as from Jupiter inlet on the east coast.

It is thus evident that Compsopogon is widely distributed and probably common in Florida; and that, although it may occur in tidal water that is practically fresh, it is characteristically an inhabitant of waters in which there is no admixture of salt.

Concerning the species of Compsopogon very little appears to be known and but few forms have been described; the brief list, exclusive of one or two uncertain species, comprising *C. leptoclados* Mont., from Guiana; *C. chalybeus* Kuetz., from Guiana, Porto Rico, and Florida; *C. aeruginosus* (J. Ag.) Kuetz., from Cuba; *C. coeruleus* (Balbis) Mont., from Florida, the Antilles, and Algeria; and *C. Corinaldi* (Menegh.) Kuetz., which has an apparently very limited distribution in Italy; to which, according to De Toni (*Sylloge* **4**: 29), should be added *C. lividus* (Hooker) De Toni from Madras. That some of these are merely synonyms seems hardly doubtful, and so far as can be

determined by published figures and descriptions few of them appear to be distinguished by characters that might not be included in the variations of a single species.

In regard to the specific determination of the species which I examined in Florida it should be mentioned that the form occurring at and near Daytona has been kindly compared by M. Bornet with specimens of *C. coeruleus* from Porto Rico in Montagne's herbarium with which it seems to be beyond question identical. The Cocoanut Grove material, however, though it can hardly be separated by any distinctive microscopic characters, is macroscopically strikingly different when fresh, being paler greenish in color, soft and pliable to the touch, and much smaller: for though its filaments are rarely more than five or six inches long those of the Daytona material normally attain a length of two feet or more, their diameter being proportionately greater; while the whole plant has a characteristically harsh stiff feel and a deeper and more striking violet-blue-green color.

Whether these peculiarities should be attributed to a specific difference, or whether they merely represent variations of a single species due to a slight difference of environment resulting from the presence or absence of tidal influence, for example, is uncertain. In either case the younger filaments and their branches consist of single rows of rather flattish cells with numerous oval to oblong or nearly spherical chloroplasts, some of which lie immediately about the conspicuous nucleus; while the greater part are peripherally disposed, being held in a protoplasmic reticulum (*fig. 1*), the active circulation in which is very conspicuous. These chloroplasts, which often exhibit a slow change of position in the protoplasmic mesh, vary but slightly in shape, and in no instance were any elongate or thread-like forms seen like those described and figured by Schmitz (*l. c.*) as characteristic of *C. coeruleus*. The filaments increase in length through intercalary divisions, and at no great distance from the terminal cell longitudinal septa begin to make their appearance, irregularly at first, but succeeding one another in such a fashion that a central axial cell comes to be separated from a layer of peripheral

cells that completely surround it and continue to undergo anticlinal divisions without regularity, while the axial cell constantly enlarges, assuming a flattened barrel-shaped form. The originally single cells of the younger filaments are thus converted into corticated segments indicated by slight constrictions in the older filaments; the monstrously developed axial cells, which are filled with watery contents and contain few chloroplasts, forming a continuous series (*fig. 14*). The corticating cells which are irregularly polygonal (*fig. 7*) form, according to Schmitz, but a single layer even in the oldest filaments; but although this seems to be invariably the case in the material from Cocoanut Grove, as shown in the figure last cited, it by no means applies to the Daytona form in which, although the original axial cells appear to remain undivided, periclinal divisions take place by which the corticating cells are separated into two well-defined layers (*fig. 12*), as is also indicated in Kuetzing's *Tabulae Phycologicae* **7**: *pl. 88, figs. b* and *f*, which may be increased to three or even four in older axes like that shown in *fig. 13*, a portion of the axial cell being indicated at *x*.

The filaments of Compsopogon are always more or less copiously branched, and although short secondary branches are sometimes developed from the corticating cells, the primary ones appear in all cases to be formed by the direct outgrowth of one of the undivided cells of the younger filaments. The alga when growing in still water may remain unattached, but is usually fixed to sticks, stones, or other plants, a short series of cells at the base remaining uncorticated and sending down rhizoidal outgrowths which form an attachment analogous to that of Porphyra.

An examination of the Cocoanut Grove material showed further that, although the cells of a majority of the plants gave no indication of any differentiation that might suggest a preparation for some form of reproduction, in others the cells of the cortex as well as those of the younger uncorticated branches had evidently divided in a characteristic fashion; one, usually the smaller of the two resultant cells, being conspicuously differentiated by reason of its darker color and more dense contents;

but although these cells were kept under observation for several hours during the afternoon and evening of the day on which they were collected no separation of spores was noticed. On the following morning, however, the dark cells were found to have disappeared, while the filaments presented the normal appearance. Although no empty cells were visible from which spores might have escaped, it was evident that something of this nature had occurred during the night. A second attempt was therefore made on the following evening; but nothing having transpired, a filament, in which many hundreds of these dark cells were present, was placed in a Van Tieghem cell shortly after nine o'clock and left till morning, when it was found to have resumed its normal appearance as before. In place of the dark cells, however, which had disappeared, a corresponding number of spherical green free cells were found lying motionless in the water at a short and rather constant distance from the filament, having evidently escaped during the night. Observations were therefore resumed at a later hour on the following evening, and at about eleven o'clock I was rewarded by seeing the first aplanospore make its escape. The same type of reproduction was repeatedly observed on subsequent occasions, and may be summarized as follows:

Formation of macroaplanospores. — Any of the superficial corticating cells, even in the oldest portions of the plant, or any of the cells of the younger filaments, even before the divisions preceding cortication have taken place, may become separated during the night into two daughter cells, in one of which the contents is more dense than in the other, and the nucleus larger and more conspicuous. As the day advances the oval chloroplasts by repeated division eventually fill it almost completely, and it begins to assume a sub-triangular outline; one of the rounded angles projecting in the form of a papilla, the wall of which is more or less distinctly thickened, the contents just beneath it becoming nearly or quite free from chloroplasts (*fig. 1*). As this cell or monosporangium matures, the basal septum by which it was originally separated from the other

daughter cell bulges more and more strongly towards the latter, and finally the discharge of the spore is accomplished, as in other instances where a papilla for dehiscence is formed, slowly at first and then more rapidly; while during its discharge, the basal septum reverses its position, the pressure exerted by the contents of the adjacent cell pushing it back into the monosporangium as the latter empties (*figs. 2–4*), the process continuing after the spore has escaped until the cavity is wholly obliterated, so that in a few hours the position of the sporangium is merely indicated by the slightly projecting margins of the orifice through which the spore escaped.

The spore, which is discharged with a force only sufficient to carry it a very short distance from the filament, is quite spherical, completely filled with chloroplasts, except for a small area (*fig. 5*) which is free from them, and possesses not even a slight amoeboid motion. In the Van Tieghem cell a few of the spores became disorganized in a short time, while a great majority, secreting a distinct wall, began to germinate on the day following their discharge; and the young plants thus formed continued to grow, forming branching filaments, for more than a week, when the culture had to be abandoned.

This type of reproduction, which was frequently met with in the material examined at Cocoanut Grove as well as at Daytona, was very uniform in all cases, but just as I was preparing to leave the former locality, a tuft of small plants was found growing on submerged grass culms in water more than usually subject to tidal influence, among which forms having the normal type of sporulation were associated with others in which it was somewhat different. Although the peculiar characteristics of this second type of sporulation may be the result of unfavorable conditions and without special significance, it may be convenient on account of their small size to distinguish the spores formed in connection with it as microaplanospores.

Formation of microaplanospores.—The formation of the cells destined to produce microaplanospores resembles the first steps in the formation of the macroaplanosporangia in that any cells

of the cortex or of the younger uncorticated portions of the filaments may divide to form two cells, one of which is usually, however, far smaller than the other and often separated from it (*fig. 10*) by an oblique septum. These small cells, instead of being converted directly into sporangia, become pushed outward so as to occupy a more or less peripheral position, and soon begin to divide independently, at first by anticlinal septa only, the early divisions sometimes following one another at right angles with such regularity that the resultant cells may be in many cases so conspicuously arranged in groups of four as to suggest aggregations of tetraspores; a resemblance, however, which soon disappears, since the divisions follow one another with increasing irregularity, and may even become periclinal. The filaments thus become covered with scattered sori (*figs. 8, 11*) irregular in form as well as in the number of cells which compose them, and might well be mistaken for groups of parasitic algæ having a habit somewhat resembling that of Xenococcus.

The discharge of spores from the cells composing these sori was not actually observed, but preparations left over night in Van Tieghem cells showed that such a discharge undoubtedly takes place, the sori being surrounded by numerous aplanospores, which, like those of the normal type, were spherical and from their regular position evidently non-motile; but were, on the other hand, far smaller (*fig. 9*) and paler from the presence of a relatively much smaller number of chloroplasts. That these microaplanospores are similar in nature to the normal spores, and that they germinate directly is altogether probable; but the exigencies of my departure made it impossible for me to determine this as well as other points in connection with them. The appearance of the older sori suggests the conditions that have been figured in connection with the supposed formation of antherozoids in Bangia; but there was no indication that the bodies thus separated in Compsopogon were sexual in function.

A careful examination of the coloring matter of these plants would be a matter of no little interest, and it may be worthy of

mention that it is so readily soluble that the bowl of water used for mounting some of the dark colored Daytona material was soon tinged a deep, somewhat violet-blue, suggesting a slight mixture of phycoerythrin with phycocyanin.

The facts above presented, although they furnish definite information concerning the reproduction of this peculiar group, are not such as to make the true position of its members less obscure than they have been heretofore, since in general they substantiate the conclusions reached by Schmitz, based, as has been previously mentioned, on the examination of dead material. As this author has pointed out, their resemblance to forms like Ceramium in the gross structure of the thallus is wholly superficial, the cortications originating very differently in the two cases, and it seems quite certain that their near relatives are not to be sought among the higher Rhodophyceæ. It cannot be denied, however, that, so far as they are known, their reproductive processes are more directly comparable with those of the Bangiaceæ than of any other group, the aplanospores of Erythrotrichia being similar to those of Compsopogon and similarly produced. That the paler "microaplanospores" of the latter genus may correspond to the "antherozoids" of the Bangiaceæ is not impossible, and although no indication of any sexual process was observed in the material examined, it may occur under other conditions or at other seasons of the year. Admitting, however, that these bodies are probably not sexual in nature, it may be remarked that the same might be said of bodies to which this function has been attributed among the Bangiaceæ; so that in either case it would seem more in accordance with the ascertained facts to leave the family in question among the doubtful Bangiales, in the absence of any other group to which they seem as closely related. Yet, although this is the position actually assigned to them by Schmitz (*l. c.*), he finally remarks, "Am besten dürfte es sein die Compsopogonaceæ als eine etwas isoliert stehende Grüppe vegetativ hoch entwickelter Formen den grünen Algen zuzuzählen."

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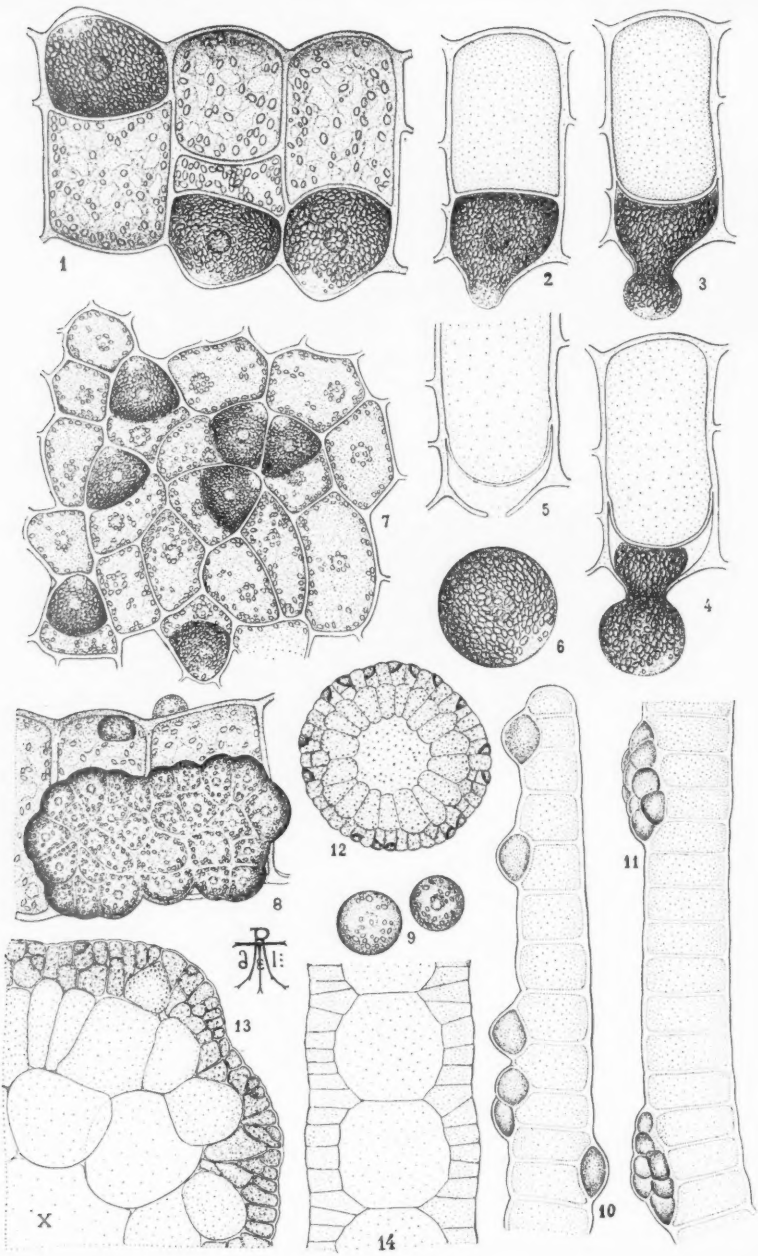

THAXTER on COMPSOPOGON

EXPLANATION OF PLATE XXI.

The figures were drawn with camera, the following Zeiss objectives and eyepieces being used. *Figs. 1–6* and *9* obj. J (water immersion) oc. 4. *Figs. 7, 8* and *10* obj. J oc. 2. *Figs. 12–14* obj. A oc. 2. *Fig. 11* obj. D oc. 4. *Figs. 12* and *13* are drawn from the Daytona material, the remainder from that obtained at Cocoanut Grove. All the figures reduced about $\frac{1}{6}$ in photo-engraving.

FIG. 1. Portion of young filament showing three macroaplanosporangia.

FIGS. 2–6. Further development of the sporangium shown at the right in *fig. 1*, the macroaplanospore discharged in *figs. 5* and *6*.

FIG. 7. Portion of cortical layer of older filament with seven macroaplanosporangia in which the aplanospores are nearly mature.

FIG. 8. Surface view of sorus of microaplanosporangia.

FIG. 9. Microaplanospores.

FIG. 10. First stages in the formation of sori in younger filament.

FIG. 11. Small sori on younger filament.

FIGS. 12–13. Transverse section of older filaments showing multiple cortication. Some of the superficial cells have formed macroaplanosporangia.

FIG. 14. Longitudinal section of filament with simple cortication.

CULTURES OF UREDINEÆ IN 1899.[1]

J. C. ARTHUR.

WITH the exception of the very important results achieved by Thaxter in the study of American Gymnosporangia, together with similar work by Farlow, Halsted, Stewart, and Carver, only a few attempts have been made in America to trace the connection experimentally between the forms of the Uredineæ.

The three stages of the clover rust (*Uromyces Trifolii*) were shown by Howell to be genetically connected and the two forms of the raspberry rust (*Gymnoconia interstitialis*) by Clinton. A slight amount of work in this line of research, chiefly of a confirmatory character, was carried out between 1889 and 1898 by Bolley, Stuart, and the writer. The yet unpublished results of Carleton, obtained as part of the work of the division of vegetable physiology and pathology at Washington,[2] complete the mention of all American efforts in this line that now occur to the writer.

The cultures made during the present season (1899), herein to be described, were conducted, with the exception of a single trial, under glass in the greenhouses of the Experiment Station at Purdue University, and upon plants in pots, the plants remaining under cover until the observations were completed. Material bearing teleutospores of a number of species was collected during the previous autumn and winter and preserved until needed by tying in loose muslin and placing on the ground out of doors.

The method generally adopted to secure infection was the same, whether æcidia, uredo, or teleutospores were in hand. The potted plant was first wet with an atomizer, parts covered with a bloom being rubbed with the fingers until the water

[1] Read before the Botanical Section of the Am. Assoc. Adv. Sci., Columbus meeting, August, 1899.

[2] Issued as Bulletin No. 16 since the paper was read.

adhered. The spores were scraped from the host material with a knife blade and placed on definite areas of the plant to be infected, the parts marked by bits of string, and a bell jar placed over the whole plant. After a day or two the bell jar was removed. With most species, if the operation had been successful, the results began to appear in six to fourteen days.

In order that the simple procedure here outlined may uniformly give information that can be relied upon, many small precautions must be observed that cannot now be spoken of. In every case it is wise to first make a drop culture, to be sure that the spores are viable.

In the following outline of the work accomplished it is impossible to go into much detail, or mention all the items of interest that are naturally brought to mind. It is also impossible to adjust the nomenclature in accordance with the new knowledge which the cultures have furnished.

1. Puccinia Phragmitis (*Schum.*) *Körn.*

The host of this species, *Phragmites communis*, does not grow in the vicinity of Lafayette, Indiana, where the work was done, and I am indebted to Dr. J. J. Davis of Racine, Wis., and Professor C. E. Bessey, of Lincoln, Neb., for teleutosporic material. Abundance of æcidia were obtained by sowing the teleutospores upon *Rumex crispus* and *R. obtusifolius*, thus confirming the results obtained by European investigators. The dates are as follows:

May 2, Teleutospores (Wis.) sown on *Rumex crispus;* May 12 spermogonia; May 15, æcidia.

May 4, Teleutospores (Wis.) sown on *Rumex obtusifolius;* May 15, spermogonia; May 16, æcidia.

May 9, Teleutospores (Neb.) sown on *Rumex crispus;* May 15, spermogonia; May —, æcidia.

May 9, Teleutospores (Neb.) sown on *Rumex obtusifolius;* May 15, spermogonia; May —, æcidia.

The preliminary drop cultures showed the most vigorous germination of teleutospores obtained with any species, and far surpassing most of those under observation. The sowings also

produced a wealth of æcidia. From these facts one would infer that æcidia on Rumex should be common, for the teleutosporic condition occurs throughout the United States. Yet I am not aware of a single authentic record of *Æcidium rubellum* being found in North America. To be sure, it occurs in the earliest published list of American fungi by Schweinitz, who was a notably accurate observer. But his remark that the spots were usually sterile, makes it fairly certain that what he collected were not æcidia, but the spots made by *fungi imperfecti*. Both Professor Bessey and Dr. Davis at my suggestion made repeated and thorough search about the places where the teleutospores were found in their localities, but saw no æcidia. Improbable as it may seem, there yet appears to be no explanation of the remarkable vigor of this heteroecismal species, but to suppose that the æcidia do occur in America, and that, so far, they have been overlooked.

2. PUCCINIA CONVOLVULI *Cast.*

The teleutospores of this very common species of rust on *Convolvulus sepium* were sown on the host, before the weather permitted it to start out of doors, and were duly followed by a rich development of spermogonia and subsequently of æcidia. It was thus experimentally shown to be an autœcious species, as has always been tacitly accepted. The dates are as follows:

May 8, Teleutospores sown; May 16, spermogonia; June 6, æcidia.

3. PUCCINIA CARICIS (*Schum.*) *Reb.*

The æcidiospores from *Æcidium Urticæ* were sown May 17 on the young leaves of *Carex stricta* and in eleven days were followed by uredospores. A sowing at the same date on *Carex cephalophora* gave no infection. This shows that *Carex stricta* is a host for *Puccinia caricis*, but there is reason to believe that it also acts as a host for other species of Puccinia. The American rusts on Carex are yet little understood.

4. UROMYCES EUPHORBIÆ *C. & P.*

There has been an almost uniform opinion among American botanists that the Æcidium occurring abundantly upon many

species of Euphorbia is not genetically related to the brown rust equally abundant upon the same hosts. The evidence I have to offer is not conclusive, but, so far as it goes, must change this view. On June 20 æcidiospores from *Euphorbia nutans* were sown upon two plants of the same species and upon one plant of *Euphorbia maculata*. Nine days afterward uredo appeared upon one of the plants of *Euphorbia nutans*, and in eleven days upon the other, followed in both cases by teleutospores after a time, the exact date not recorded, but the plant of *E. maculata* showed no infection.

Instead of speculating upon such meager data, I am inclined to believe that *Uromyces Euphorbiæ* is an autœcious species, and to await further cultures showing if it is separable into races.

5. PHRAGMIDIUM SPECIOSUM *Fr.*

The intimate association of a cæoma, which is not distinguishable from *Cæoma miniata* Schl., with this exclusively American species of Phragmidium, would have been accepted as sufficient evidence of its genetic connection, if the same form apparently had not been considered in Europe as the first stage of the very different *Phragmidium mucronatum*, a species that is also common in this country.

At the time when the teleutospores of *Phr. speciosum* were in germinating condition no potted plants of native roses were available, and sowings were made upon the leaves of a tea rose, the Kaiserin Augusta Victoria. The work was done by my assistant, Mr. William Stuart, and the dates are not at hand, but in due course of time many pustules of cæoma appeared. These bore every resemblance to the usual form, although they did not become very large, which may have been due to the host not being congenial.

It is probably safe to assume that the rose cæoma in this country belongs wholly to *Phragmidium speciosum*, or else that there are two species not at present separable.

6. TRIPHRAGMIUM ULMARIAE (*Schum.*) *Lk.*

This species of rust, not heretofore reported for America, so far as the writer knows, was found in considerable abundance

this spring near Lafayette, Ind., upon *Ulmaria rubra* (*Spiræa lobata*), in the bright red cæoma stage. Feeling at first uncertain of the identity of the rust, the cæoma spores were sown upon the Ulmaria, and also upon Salix, Convolvulus, and Ipomœa, with the result that it grew only upon Ulmaria, producing at first uredospores and afterward teleutospores. An after-sowing of uredospores upon Ulmaria gave a crop of more uredospores. The dates are as follows:

May 17, Cæomospores sown on *Ulmaria rubra;* May 30, uredo; July — teleutospores.
May 17, Cæomospores sown on *Salix longifolia;* no infection.
May 23, Cæomospores sown on *Convolvulus sepium;* no infection.
May 24, Cæomospores sown on *Ipomœa pandurata;* no infection.
June 16, Uredospores sown on *Ulmaria rubra;* July —, uredospores.

7. Puccinia Americana *Lagh.*

This grass rust on various species of Andropogon is very common throughout North America, but has been generally confounded with *Puccinia Andropogi* Schw., which has the same range and affects the same hosts. The teleutospores are barely distinguishable, but the uredospores are entirely unlike those of *P. Americana*, being large and thin walled, those of *P. Andropogi* small and thick walled. The detection of the æcidium is due to the careful observation of Mr. William Stuart, who noticed that plants of *Pentstemon pubescens*, growing near Andropogon bearing teleutospores of the previous year, were well covered with æcidia (*Æcidium Pentstemonis* Schw.), while the same species in other localities was quite free. With this hint sowings were undertaken. Teleutospores from *Andropogon scoparius* were sown on *Pentstemon pubescens* and æcidia appeared in great abundance and vigor; æcidiospores were sown on Andropogon and large, thin-walled, brown uredospores appeared. The results were ample and complete, and were further emphasized by similar results subsequently obtained by Mr. Stuart. The dates are as follows:

May 3, Teleutospores from *Andropogon scoparius* sown on *Pentstemon pubescens;* May 11, spermogonia; May 20, æcidia.

May 4, Teleutospores from *A. furcatus* sown on *Œnothera biennis;* no infection.

May 15, Ædiospores from *P. pubescens* sown on *A. scoparius;* May 29, uredo.

8. PUCCINIA ANGUSTATA *Pk.*

The detection of the æcidium of this common rust on Scirpus was also due to a fortunate observation. It was noticed that some plants of Lycopus, growing within a few feet of *Scirpus atrovirens* covered with last year's teleutospores, were well besprinkled with æcidia (*Æcidium Lycopi* Ger.), while plants some distance away were free. Sowings of æcidia were made on the leaves of the Scirpus and characteristic uredo obtained. The hint was secured so late in the season that only one sowing was possible, but the result is thought to be measurably reliable.

May 23, Ædiospores from *Lycopus Americanus* sown on *Scirpus atrovirens;* June 6, uredo.

9. PUCCINIA WINDSORIÆ *Schw.*

This rust occurs, often in great abundance, upon the much benamed grass, *Triodia cuprea* (*Sieglingia seslerioides* Scrib.), which in the days of Schweinitz was standing in the genus Windsoria. The name of the rust was applied in Burrill's *Parasitic Fungi of Illinois* fourteen years ago, to the very different rust on Muhlenbergia, hence great confusion has arisen, and in nearly all recent lists and treatises the name is misused.

The hint that led to successful cultures came from an observation upon proximity, as in the previous cases. A small shrub of *Ptelea trifoliata* was made conspicuous by the bright yellow spots of *Æcidium Pteleæ* B. & C., and not ten feet away was a large clump of the grass with the dead stems and leaves black with teleutospores. Successful sowings of æcidiospores were made on the grass, but the season by this time had advanced so far that germinating teleutospores were no longer obtainable with which to try the reverse cultures. The dates are as follows:

May 15, Teleutospores sown on *Ambrosia trifida;* no infection.

May 17, Teleutospores sown on *Napæa dioica;* no infection.

June 8, Ædiospores sown on *Triodia cuprea;* June 15, uredo.

June 16, Ædiospores sown on *Triodia cuprea;* June 23, uredo.

10. PUCCINIA VILFÆ *A. & H.*

This species of rust, better known as *P. Sydowiana* Diet., is necessarily restricted in the vicinity of Lafayette to the few localities where the host, *Sporobolus longifolius*,[3] is to be found. My attention was called to the fact by Miss Lillian Snyder that in such localities the exceedingly common upright verbenas were richly covered with *Æcidium verbenicola* K. & S., and with no other species of æcidia in the vicinity. Going over the ground myself, I found that the verbena plants, *Verbena stricta* being particularly abundant, were more thickly studded with æcidia the closer they stood to tufts of rusted Sporobolus, and that fifty feet away from such source of infection they would be entirely free.

Cultures were undertaken in 1898, but too late in the season to secure results. In the mean time a morphological resemblance was observed between the spores of *Æcidium verbenicola* and the uredospores of *Puccinia Vilfæ*, that gave another hint at genetic relationship. Both sorts of spores were approximately obovate, with colorless walls, greatly thickened at the apex, and papillose instead of echinulate. Successful cultures have shown that these rather uncommon characters meant more than a coincidence in this case. It is the first time, so far as the writer knows, that any significant resemblance has been pointed out between the spores of æcidia and uredo of the same species.

For some unexplained reason I was unsuccessful in germinating the teleutospores of *P. Vilfæ*, although they were taken a number of times directly from the field. But with æcidiospores the results were ample and convincing. The dates are as follows:

May 31, Æcidiospores from *Verbena stricta* on *Sporobolus longifolius;* June 10, uredo.

June 9, Æcidiospores from *Verbena stricta* on *Sporobolus longifolius;* June 21, uredo.

[3] Since this paper was read I have discovered that the grass under observation was *Sporobolus longifolius* (Torr.) Wood, instead of *S. asper*, as given in the manuscript, and printed in Science **10**: 565, and Proc. A. A. A. S. **48**: 299. The latter grass does not grow in this region.

11. PUCCINIA PERIDERMIOSPORA (*E. & T.*) *Arth.*

In studying the grass rusts it was noticed that a form on Spartina, well represented in American herbaria and usually called *Puccinia Phragmitis*, had uredospores similar to those of *Puccinia Vilfæ*, just described. I searched through my collection of Æcidia to see if any species with corresponding apically thickened spores could be found, and was rewarded in the case of *Æcidium Fraxini* Schw. With this morphological hint as the sole guide cultures were undertaken.

Spartina does not grow within many miles of Lafayette, and I am indebted to the kindness of Professor C. E. Bessey, of Lincoln, Neb., and Mr. H. H. Hume, of Ames, Iowa, for teleutosporic material upon *Spartina cynosuroides*. The teleutospores germinated with marked vigor, and were first sown on *Ptelea trifoliata*, the small plants obtained being mistaken for Fraxinus. When the mistake was discovered, and sowings were made on *Fraxinus viridis*, infections were first secured. As no small plants of Fraxinus were available, the spores were sown upon cut twigs placed in water in the greenhouse, and upon a low branch of a large tree out of doors. There could be no fear of spontaneous infection, as the species does not occur in the region, either upon Spartina or Fraxinus, but the usual precautions were taken. The sowings were both successful. The dates are as follows:

May 8, Teleutospores (Neb.) sown on *Ptelea trifoliata*; no infection.
May 9, Teleutospores (Neb.) sown on *Ptelea trifoliata*; no infection.
May 9, Teleutospores (Iowa) sown on *Ptelea trifoliata*; no infection.
May 15, Teleutospores (Neb.) sown on *Ptelea trifoliata*; no infection.
May 17, Teleutospores (Iowa) sown on cut twigs of *Fraxinus viridis*; May 24, spermogonia; June 6, æcidia.
May 17, Teleutospores (Neb.) sown on tree out of doors of *Fraxinus viridis*; May 29, spermogonia; June 8, æcidia.

SUMMARY.

The following are the eleven species of Uredineæ, whose æcidial and teleutosporic forms have been definitely connected by cultures:

1. *Puccinia Convolvuli* Cast. and *Æcidium Calystegiæ* Desm. with sowings of teleutospores.
2. *Puccinia Phragmitis* (Schum.) Körn. and *Æcidium rubellum* Pers. with sowings of teleutospores.
3. *Puccinia Americana* Lagh. and *Æcidium Pentstemonis* Schw. with sowings of æcidiospores and teleutospores.
4. *Puccinia Windsoriæ* Schw. and *Æcidium Pteleæ* B. & C. with sowings of æcidiospores.
5. *Puccinia Vilfæ* A. & H. and *Æcidium verbenicola* K. & S. with sowings of æcidiospores.
6. *Puccinia peridermiospora* (E. & T.) Arth. and *Æcidium Fraxini* Schw. with sowings of teleutospores.
7. *Puccinia Caricis* (Schum.) Reb. and *Æcidium Urticæ* Schum. with sowings of æcidiospores.
8. *Puccinia angustata* Pk. and *Æcidium Lycopi* Ger. with sowings of æcidiospores.
9. *Uromyces Euphorbiæ* C. & P. and *Æcidium Euphorbiæ* Am. Auct. with sowings of æcidiospores.
10. *Phragmidium speciosum* Fr. and *Cæoma miniata* Am. Auct. with sowings of teleutospores.
11. *Triphragmium Ulmariæ* (Schum.) Lk. and *Cæoma Ulmariæ* Thüm. with sowings of æcidiospores and uredospores.

PURDUE UNIVERSITY,
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BRIEFER ARTICLES

ORIGIN OF THE THALLUS, ALTERNATION OF GENERATIONS, AND THE PHYLOGENY OF CUTLERIA.[1]

THE Cutleriaceæ (Cutleria and Zanardinia) may be considered among the most interesting and remarkable forms of the Phaeosporeae.

The two fronds, sexual and asexual, of the single species of Zanardinia (*Z. collaris*) are identical. The genus Cutleria, represented in Europe by two species, has a sexual thallus whose structure and development is very different from the asexual form. The oogonia and antheridia are borne upon the plant named Cutleria, whose thallus is composed of and formed through the union of marginal filaments remaining free upon the periphery, and becoming divided by partitions with the thickening of the thallus following the fusion. So the thallus is both a pseudoparenchyma and a true parenchyma.

The sporangia are borne in the upper surface of Aglaozonia, which has a creeping habit, and grows by marginal cell division like Zonaria. It now seems to be established that *Aglaozonia parvula* is the asexual form of *Cutleria multifida*, and one may suppose with Falkenberg that *A. chilosa* is the asexual form of *C. adspersa*. In reality, however, this supposition rests upon the fact that we do not know in Europe any other species of Cutleria or Aglaozonia.

But I have found at several points on the coast of the gulf of Gascony a new Aglaozonia, the *Zonaria melanoidea* of Schousboe, discovered at the beginning of the century at Maroc, and not reported since, whose Aglaozonia nature has remained unrecognized. For various reasons I consider *Aglaozonia melanoidea* to be the sporophyte of *C. adspersa*. If that form has not been seen up to the present in the Mediterranean where *C. adspersa* is not rare, it is without doubt because of its very great resemblance to Ralfsia. But since we do not know the gametophyte of *A. chilosa*, and as the Cutlerias are plants with a rather large thallus, conspicuous and easily recognized, it is

[1] This contribution is in part a résumé by PROFESSOR SAUVAGEAU of his paper entitled "Les Cutleriaceæ et leur Alternance de Générations," Ann. d. Sci. Nat., Bot. 10: 265. 1899. Translated by Dr. Bradley M. Davis.

improbable that the Mediterranean hides a third species of Cutleria. Therefore *A. chilosa* multiplies always non-sexually, without alternation of generation, as is also the fact with *A. parvula* in northern Europe. If it possesses a gametophyte it is without doubt some exotic species (*C. compressa*, *C. pacifica*) as yet insufficiently studied.

As for the culture of oospheres of Cutleria, it has given up to the present very conflicting results. Thus in the middle of the century Thuret obtained through the germination of parthenogenetic oospheres some small plants somewhat resembling an Ectocarpus, which no one has since found, and which I call form *Thuretiana* of germination. But Falkenberg has obtained from the germination of fertilized oospheres (the only ones that did germinate in his cultures) some strange plants, at first with the form of a small upright column, at the base of which is borne, after it has arisen, a creeping plate comparable to Aglaozonia; these plants I call form *Falkenbergiana*. There is also a form *Falkenbergiana* that has been obtained by Church, but from the germination of parthenogenetic oospheres, in this respect differing from the results of Thuret and Falkenberg. Finally the zoospores of *A. parvula* have given to Church plants which, like the preceding, have the creeping plate-like thallus of Aglaozonia, but whose column ends at the summit in filaments (not fascicled) which bear the reproductive organs of Cutleria. I have named this new example of germination form *Churchiana*. Some plants comparable to these have developed in the cultures of Kuckuck.

How shall such divergent results be reconciled? It may always be borne in mind that the preceding authors have never obtained uniformity of germination in their cultures.

Now I have found *C. adspersa* at Guéthary (Basses-Pyrénées) when the male plants were more numerous than the female. The discharge of the sexual elements was abundant, and took place readily in my cultures. However, I have never obtained fertilization; the oospheres did not even attract the antherozoids. At times they germinated very readily parthenogenetically and gave always and characteristically the form *Falkenbergiana*. This is in agreement with the observations of Church, but my results are the more surprising, for the English author found only a few or no male plants; his female plants were therefore unfortunately parthenogenetic.

It occurred to me to look for germination of spores in nature upon the Cutleria plants themselves. I have found a great many of the

sporelings *Thuretiana* and *Falkenbergiana* and rarely some *Churchiana*. One finds all the intermediate conditions between very young *Thuretiana* in the form of a simple filament, and young Cutleria fascicled or with free filaments at the margin; consequently the form *Thuretiana* gives rise to the thallus of Cutleria, and is not an abnormality of the cultures as Falkenberg believed. The sporelings *Falkenbergiana* were truly thalloid, and I have shown that the column takes on a larger thallus than would be supposed from the cultures of the preceding authors. I was able to follow sufficiently far the development of the creeping Aglaozonia-like plate whose structure resembles that of *A. melanoidea*.

This is, therefore, the first time that these plants have been found united, but what of their origin? They cannot be attributed to the zoospores of *A. melanoidea*, for during all the time of my observations these plants remained sterile. Since the parthenogenetic oospheres in my cultures of Cutleria gave on germination form *Falkenbergiana*, it is to be supposed that identical plants found in nature in the same locality and at the same time would have the same origin. And since in this situation the male individuals are more numerous than the female, one may admit the antherozoids should play a part, and that fertilization, although not operative in my cultures, occurs in nature, and consequently that the form *Thuretiana* owes its development to fertilized oospheres. As for the form *Churchiana*, that is an anomaly, an example of *Falkenbergiana* with the column changed at the tip into Cutleria; it is interesting in the same manner as a flower of some phanerogam with metamorphosed petals and stamens.

If the results obtained by previous authors are reconciled, we must acknowledge from these conclusions that alternation of generations is not necessary, but rather, as one may say, facultative. Moreover, an oosphere of Cutleria, whether it be parthenogenetic or fertilized, may give on germination either Cutleria or Aglaozonia. Similarly, a zoospore of Aglaozonia may produce Cutleria or Aglaozonia. But we do not know the conditions that govern the development from the zoospores or oospheres in either case.

As for the affinities of Cutleria, they are numerous. The sexual thallus (Cutleria proper) has a method of development that is found in the Sporachnaceæ; it bears oogonia and antheridia similar to those of Sphacelariaceæ and Tilopterideæ. The asexual thallus (Aglaozonia) recalls certain of the Sphacelariaceæ (Battersia, *Sphacelaria olivacea*) and certain of the Dictyotaceæ (Zonaria, Padina).

But Aglaozonia is not a direct product of germination; it is a secondary product, always formed from a pro-embryo or small column. Now the column produces normally at its base the creeping thallus of Aglaozonia, and abnormally at its tip a frond of Cutleria (form *Churchiana*). Here are the extremes, Cutleria and Aglaozonia, but the column has a place between, although its structure differs clearly from both. It appears to us to be a necessary and fundamental organ, probably of great importance phylogenetically. In its structure the column resembles greatly those of Myriotrichia and Litosiphon; it is possible that in teratological conditions it forms reproductive organs, which knowledge would throw strong light upon its affinities. I consider Cutleria, therefore, as a union of three genera, Cutleria proper, Aglaozonia, and the column of some unknown genus.—C. SAUVAGEAU, *University of Dijon, France.*

SOME PLANTS OF NEW MEXICO.

CASTILLEIA CONFUSA × ACUMINATA, n. hyb.—Leaves variable, some just as in *C. acuminata*, others on the same plants very narrow, almost linear, as in *C. confusa;* bracts with lateral narrow lobes 3 to 4^{mm} long in the dried plant (1–1.5^{mm} in *acuminata*, at least 4^{mm} in *confusa*); apical parts of bracts delicately tinted with pink (yellow in *acuminata*, bright red in *confusa*); galea 6^{mm} (8^{mm} in *confusa*, hardly 5^{mm} in *acuminata*); plant rather rougher than *acuminata*.

Harvey's Ranch, near Las Vegas, New Mexico, 9600^{ft}, August 22, 1899. (*Wilmatte Porter* and *T. D. A. Cockerell*). This is clearly a hybrid, and was found growing in a meadow along with quantities of *C. confusa* Greene, and *C. acuminata* (Pursh).

SIDALCEA CANDIDA **tincta**, n. var.—Similar to *S. candida*, but petals suffused with pink toward their ends; anthers before dehiscence bright pink; on dehiscence turning black; pollen white; petals barely emarginate, 12^{mm} long, 10.5 broad; calyx lobes broad at base, narrow at apex, pointed, about 6^{mm} long and 3^{mm} broad at base; cauline leaves a rather light bright green, palmately 5 to 7-parted, or cleft nearly to the base, the divisions about 60^{mm} long and 17^{mm} broad, on the upper leaves entire, on the lower 2 or 3-cleft at the ends; stem light green, shining, glabrous; calyx and peduncles rough and more or less hairy; carpels 8, smooth when ripe, with an upright hairy beak.

Harvey's Ranch, near Las Vegas, N. M., 9600ft, July 25, 1899 (*Flora Beschle*) and August 22, 1899 (*Cockerell*). This is a distinct looking plant, but it represents only a peculiar local tendency, not a separate specific type.

SIDALCEA NEOMEXICANA Gray.— Good material of this, from Las Vegas, N. M., and elsewhere, has the mature carpels strongly reticulated. I thought I had a new species, but it is evidently only *neomexicana*. In the herbarium of the N. M. Agricultural College, Professor E. O. Wooton has specimens showing smooth and reticulated carpels, collected at the same time and place.

CLEMATIS OCCIDENTALIS[2] **albiflora,** n. var. — Sepals white.

Common at Beulah, New Mexico (*W. Porter; Cockerell*), where the typical form, with purplish-blue sepals, is rare.

CALOCHORTUS GUNNISONI **perpulcher,** n. var. — Petals larger, 40–42mm long and 45mm broad, pale primrose yellow, a large purple basal spot, irregular purplish bands as in type, transverse gland yellow, about 10mm diameter, the breadth of the petal at this level being 18mm; style blue; stigma pale sea-green, with dark mottling; anthers pale yellow; petals almost white beneath, greenish and finely streaked with dark blue on basal portion; sepals colored like basal half of petals.

Harvey's Ranch, near Las Vegas, N. M., July 25, 1899 (*Flora Beschle*); Beulah, N. M. (*Wilmatte Porter*). This stands out well from the typical *C. Gunnisoni* of Colorado, which grew all round my former place of residence in that state.— T. D. A. COCKERELL, *Mesilla Park, New Mexico.*

[2] *Atragene occidentalis* Hornem. Hort. Hafn. 520. 1813.

CURRENT LITERATURE.

BOOK REVIEWS.

Bailey's Cyclopedia.[1]

In America there has been but one cyclopedic work on horticulture, viz., Henderson's *Handbook of Plants*, published in 1881, with a second edition in 1890, each edition in one volume. Accordingly, botanists, as well as horticulturists, have been looking forward with eagerness to the appearance of Professor Bailey's great work. The opening paragraph of the preface tersely states its purpose: "It is the purpose of this work to make a complete record of the status of North American horticulture as it exists at the close of the nineteenth century. The work discusses the cultivation of fruits, flowers, and garden vegetables, describes all the species which are known to be in the horticultural trade, outlines the horticultural possibilities of the various states, territories, and provinces, presents biographies of those persons, not living, who have contributed most to the horticultural progress of North America, and indicates the leading monographic works relating to the various subjects."

Only Professor Bailey would have undertaken this tremendous task. It is probable that no one, excepting the editor and his immediate associates, can appreciate the amount of detail which such a work must involve. The editor has set down some of the items as follows: "More than 10,000 species of plants in cultivation; almost every important species phenomenally variable, sometimes running into thousands of forms; every species requiring its own soil and treatment, and sometimes even minor varieties differing in these requirements; limitless differences in soils and climates in our great domain, every difference modifying the plants or their requirements; a different ideal in plant-growing and plant-breeding in the mind of every good plant-grower; as many different kinds of experience as there are men; many of these men not facile with the pen, although full of wholesome fact and experience; the species described in books which deal with the four corners of the earth; very few botanists who have given attention to the domestic flora." The editor has said that "the most difficult part of the making of a cyclopedia is to project it. Its scope and point of view must be determined before a stroke of actual work is done. This much done, the remainder is labor

[1] Bailey, L. H.—Cyclopedia of American Horticulture. Assisted by Wilhelm Miller and many expert cultivators and botanists. Illustrated with over 2000 original engravings. In 4 vols. Vol. I. A–D. 4to. pp. xxii + 509. New York: The Macmillan Company. 1900. $5.00.

rather than difficulty." For more than ten years Professor Bailey has been moving in the direction of this cyclopedia, much of his published work in the meantime being "material on the way" to the larger venture. The "Annals of Horticulture," published for five years, was the first tangible result, "designed to be a witness of passing events and a record of progress."

To compile a cyclopedia by using other cyclopedias involves drudgery, but presents no special difficulties, and results in no special merits. In Bailey's *Cyclopedia*, however, the work is new from start to finish, both in text and illustrations, and the list of collaborators shows that the most expert assistance has been obtained.

The illustrations, too, deserve special mention for the happy combination of scientific and artistic excellence, and it has been one of the rules of the "make up" that "wherever the book opens an engraving will be seen." Besides, the book is distinctly American in its flavor, fully setting forth American experience and conditions.

The matter may be arranged under three heads: cultural, taxonomic, and morphological, and the sequence seems to express their relative importance, as "the stress is laid upon the plants as domesticated and cultivated subjects."

In reference to the cultural parts the reviewer can express no opinion, but botanists are familiar with Professor Bailey's standard in such matters, and need no assurance as to the freshness and vigor of this portion of the work.

The following example, under the title *Acacia*, will serve to illustrate the taxonomic portion of the work. The genus is described briefly, in language as non-technical as possible, and a synopsis of fifty-three species is given, including all those in the American trade. The synopsis consists of an analytical key, brief descriptions, and essential synonymy, just as in an ordinary manual, so that the *Cyclopedia* becomes a great manual for all plants in cultivation in America.

The morphological titles, such as "flower," etc., are to appear chiefly in subsequent volumes, and comment on this topic will be deferred.

To the botanist the *Cyclopedia* is a mass of most valuable information, bringing together, as it does, into available and properly edited form, the immense contribution of facts from horticulturists to the whole evolutionary doctrine, and enabling the morphologist to know what form he is handling and what has been done with it. The work should find its place in the libraries of all botanical laboratories as well as in those of practical horticulturists.—J. M. C.

Minnesota plant life.

FOR the second time botanists have had the pleasure of seeing a book that has for its topic the vegetation of one of our states. Pound and Clements'

Phytogeography of Nebraska was a work that marked a distinct advance in the ecological investigation of our country. MacMillan has now given us an attractive presentation of the plant life of Minnesota.[2] The purpose of this work, however, is different from that of the earlier one. Its style is less technical and the pages abound in illustrations. The author distinctly states that his purpose is the botanical education of the people of Minnesota, not through the use of the book as a text, but rather through its intelligent perusal by the wide-awake boys and girls of the state. The author remarks that the book is more the offspring of the woods and lakes than of the laboratory and library. The work, then, is to be judged from the standpoint of the people rather than from the standpoint of the botanist, although Professor MacMillan endeavors to make the book scientific as well as popular.

The introductory chapter deals with the relation of the Minnesota flora to that of the whole country, and the author gives a brief discussion of the forest and prairie with their lines of tension. Then follows a chapter on the wanderings and migrations of plants. Most of the book (390 out of 525 pages) is taken up with a popular and readable description of the plants of the state, beginning with the slime-molds and closing with the composites. Common names are given in most instances, even if they have to be introduced for the occasion, as in the case of many of the lower forms. The cryptogams are given great prominence, and are well illustrated by a number of excellent half tones. The feature of this part of the work is the untechnical description of the various species. In most cases the ecological and economic relations of the plants are most fully treated, as they should be in a work of this kind. More technical chapters are also introduced for those who are interested in the philosophy of the subject; such chapters are those that deal with alternation of generations and the meaning of the seed habit.

The latter part of the book is distinctly ecological, treating the adaptations of plants to their surroundings and also the plant societies in the familiar way. The last two chapters are physiological, dealing with nutrition and reproduction.

This work does not pretend to be an addition to science, although many of the photographs may be regarded as contributions along this line. The wealth of illustration is one of the strongest features of the book and it is doubtless superior in this regard to any work that has yet appeared in America. Not only are the illustrations numerous, but they show what they are said to show, which is not true of all illustrated books. The style is very

[2] MACMILLAN, CONWAY: Minnesota Plant Life. Report of the Survey, Botanical Series III. Imp. 8vo. pp. xxv + 568. *pl. 4. figs. 240.* St. Paul, Minn.: Published by authority of the Board of Regents of the University for the People of Minnesota. 1899.

attractive and must appeal not only to the botanical reader but to all who have a love for nature. The book abounds in catchy phrases and presents plants almost as though they were human. One result of the study of this book ought to be a more widespread recognition of plants as living things, which have rights to be respected.

Adverse criticisms upon *Minnesota Plant Life* are few, and are mainly incident to the popularization of a scientific subject. However, it is very doubtful whether a book of this character is the place in which to exploit such ideas as these: peat bog plants have xerophytic structures so as to prevent the rapid passage of water through the tissues (p. 436); the inclusion of salvinias and bladderworts under the term plankton (p. 443); extreme views on the significance of colors, in which blue as well as red is called a "warming-up" color, so that blue and red flowers are said to come from northern climes and yellow flowers from warmer climes, and that spring and fall flowers are blue or red, while summer flowers are yellow (p. 426); vernal plants are said to have come from the north, and the more leisurely plants from the south; sunflowers and their allies are the highest of the plants and may form the forests of the future (p. 471). All of these ideas are extremely fanciful, if not untrue. They may properly have a place in poetry and in the graduate classes in ecology; but the popular mind is already too full of such ideas, and it seems a pity that botanists should further encourage this kind of thinking by using it in popular works.— HENRY C. COWLES.

A popular treatise on bacteria.

IN ONE of the recent volumes of the Science series the author, Mr. George Newman, attempts "to set forth a popular scientific statement of our present knowledge of bacteria."[3] The following are the principal topics discussed: the biology of bacteria; the bacteria of water, air, and soil; bacteria in milk and other foods; bacteria in fermentation; immunity and antitoxins; bacteria and disease; and disinfection. This list of subjects is an attractive one. The literary style is easy and in many ways the book seems to possess those qualifications which will assure for it a ready sale.

Books on popular science, especially if pleasing in style and manufacture, reach a vast number of readers and form a very important educational factor. Often a single book is the only treatise upon a given subject that falls into the hands of the reader. In such instances the book stands as an "authority" in the reader's mind. Because of this exalted position, which may be reached by the popular treatise with or without good reason, such books may properly be subjected to even more searching criticism than are more abstruse texts.

[3] NEWMAN, GEORGE: Bacteria, especially as they are related to the economy of nature, to industrial processes, and to the public health. 8vo. pp. xiv + 348; *illus.* New York and London: G. P. Putnam's Sons. 1899.

This is all the more necessary since they are intended for a class of readers who are incapable of sifting the true from the false.

In the book in hand statements similar to the following are frequent. "Many species . . . . rise to the surface and lodge in the pellicle to form their seeds" (p. 19). Such a use of the word "seed" is unwarranted even in a popular treatise. On page 16 may be found this erroneous statement: "*Micrococcus agilis* is the only coccus which has flagella and active motion." On page 36 the word "attenuated" is used in such a way as to lead the unwary to believe that attenuation is synonymous with decrease in vegetative power. *Bacillus tuberculosis* is a well-known example of an organism which decreases in virulence as it increases in vegetative power in artificial culture. On page 68 is given a very questionable method for the diagnosis of cholera, viz., the direct examination of flakes of detached epithelium.

As types of loose or misleading sentences, which are very common, may be noted the following: "It will be understood that bacteria do not live in air" (p. 107), a statement that quite fails to express the meaning intended. "The gases (!) essential to plants are four, carbon dioxide, hydrogen, oxygen, and nitrogen" (p. 146); and again on p. 147, "Here then we have the necessary food of plants expressed in a sentence: *water, gases, salts, the most important and essential gas and some of the salts being combined in nitrates.*" "The reduction of a nitrite is a common property of bacteria" (p. 150). The expression "organismal process" (p. 29) is surely very unusual. "Pure cholera bacillus in suspension and typhoid bacillus in suspension were passed through these filters and not a single bacillus was detectable in the filtrate" (p. 80). While this loose diction may not lead to error, it does cost the reader much time to discover the intended meaning.

On the whole, the book is like so many other popular works, a mixture of good and bad, the accurate and the misleading. Because of the looseness and the actual error it can only be commended to the discriminating student, for whom, least of all, it was intended and who needs it least. For popular reading a better book is necessary.—F. L. STEVENS.

The forestry problem.

THE announcement that Yale University is to have a school of forestry, and the appearance of a number of publications dealing with different phases of the forestry question, show that the crusade for a better understanding of the problem is having its effect. A recent work by Mr. Bruncken on North American forests and forestry[4] is not intended to be a guide for the professional forester, but rather to make clear to the general reader the exact condition of affairs. It is written for those who take a living interest in all

[4] BRUNCKEN, ERNEST: North American forests and forestry. Their relation to the national life of the American people. 8vo. pp. 262. New York: G. P. Putnam's Sons. 1900.

questions affecting the welfare of the nation, and who love the life of nature without standing apart from the more strenuous current of human affairs.

The chapter on the North American forest contains an excellent résumé of distribution of forests before they were changed by the influence of man. It is shown that the forest is controlled by certain definite factors and that the struggle of the forest with the prairie and the bog is constant, as is also the struggle between the individual trees of the same forest; so that a correct understanding of the complex conditions which determine the distribution of trees becomes of utmost importance in silviculture.

The next chapter contains a brief history of the relation of the forest to the growth of the nation. It was absolutely necessary for the pioneer to clear the forest, and the damage his immediate successors have done by carrying this destruction too far must be repaired by the present generation. The author takes a very optimistic view of the future condition of the forests.

Forest finance and management, forestry and government, protecting forests from fires and thieves, and forestry and taxation are so treated as to show that the author is well informed on these phases of the forestry problem. In chapters on reform in forestry methods, and forestry as a profession, a brief history of the reform is given and some mistakes are pointed out. Attention is called to the number of schools of forestry recently established, and to the practical results obtained by applying scientific methods to certain plots, which the Forestry Division of the U. S. Department of Agriculture is now encouraging owners to do.

The volume is not without literary merit; the author's style is clear and logical, and at times, as in the case of the description of a forest fire, fascinating. As the author well says, the question of forestry cannot be solved by sudden bursts of enthusiasm, and does not appeal to man's emotional nature. Sensible treatment of our forest wealth will come only through the education of the public along this line. The book deserves a wide reading because it will contribute to this end. — H. N. WHITFORD.

MINOR NOTICES.

IT IS a pleasure to receive a paper which possesses so many good qualities as the recension of the Mexican and Central American Umbelliferæ lately issued by Messrs. Coulter and Rose.[5] In examining this work one is impressed no less by its clear presentation of diagnostic and bibliographic essentials than by a judicious exclusion of irrelevant matter. The authors do not, for instance, attempt to give their work impressive proportions or an erudite appearance by adding under each genus and species all the synonymy which could have been cheaply compiled from the *Index Kewensis*

[5] COULTER, J. M. and ROSE, J. N.: A synopsis of Mexican and Central American Umbelliferæ. Proc. Wash. Acad. Sci. 1:111–159. Jan. 1900.

If it seems best to give copious bibliography under one species, they do not feel it essential to cite for symmetry an equal amount of almost meaningless references under another.

The paper brings together in convenient form the results of considerable scattered activity, and the extent of recent work upon the group may be inferred from some introductory statistics. In 1880 Mr. Hemsley enumerated in the *Biologia Centrali-Americani* 25 genera and 76 species of Umbelliferæ. Messrs. Coulter and Rose — who, to the territory covered by Hemsley's work, add Lower California — recognize 39 genera and 182 species, including about 40 which are here described for the first time. It is interesting to note that this considerable increase in known species is about proportionate to the similar additions in the gamopetalous Mexican genera, which have been recently revised. It testifies not merely to the unforeseen wealth of the Mexican flora but also to the success of the many skilled collectors who, during the last two decades, have explored its vegetation with such diligence. Among these may be mentioned especially Messrs. Pringle, Palmer, J. D. Smith, Brandegee, Altamirano, Millspaugh & Gaumer, Nelson & Goldman, Rose, Hartman & Lloyd, L. C. Smith, Conzatti & González, C. L. Smith, Dugès, and Lamb.

The Umbelliferæ form a very natural group in which floral structure is remarkably constant. In their paucity of floral characters they may be compared to the Cruciferæ and, like them, have for the most part good species, comparatively few varieties, and (*exceptis neglectis*) technical rather than convincingly natural genera. It is a group, in fact, where numberless generic changes could be easily and plausibly initiated by anyone with a conscious or unconscious *penchant* for disagreement with his predecessors. The work of the present authors, however, is distinctly constructive rather than revolutionary.

In a paper where many names are cited a few slips are well-nigh inevitable; thus in the present instance *Seeman*, *Couthony*, and *A. L. Smith* have an unfamiliar look. The many specific names, which the authors have been obliged to coin, are mostly the simple and familiar descriptive terms of the *glauca*, *serrata*, and *rigida* type, with no such unscholarly linguistic jumbles as *pseudoparviflora*, *heterappendiculata*, *Saxifragopsis*, *parvicarpum*, etc., which have of late so frequently marred the publications from other American botanical establishments, although rarely found in the writings of our more classical transatlantic colleagues. Another point which merits special mention is the scrupulous care with which the authors have avoided the publication of manuscript or herbarium names in their synonymy — a useless practice which, notwithstanding the emphatic protest of Mr. B. Daydon Jackson and others, is still too prevalent.

The revision is illustrated by ten excellent plates and numerous text cuts. — B. L. ROBINSON.

PROFESSOR F. LAMSON-SCRIBNER has published the second part of his *American Grasses* as Bulletin 17 of the Division of Agrostology. It will be remembered that every species is illustrated. Part I contained illustrations of 302 species, and Part II adds 325. The interesting statement is made that of the 627 species now illustrated, "19 may be regarded as characteristic of the Atlantic coast region, 83 of the region of the Gulf of Mexico, 92 of the southwest, including the states of Texas, New Mexico, Arizona, and southern California, 74 of the states of California, Oregon, and Washington, and 61 of the Rocky mountain region, of which 19 may be regarded as more properly the prairie species of that region." This series will certainly prove very useful in the identification of grasses, a family usually left to the expert.

Bulletin 21 of the same division contains a revision of the North American species of *Chætochloa*, by F. Lamson-Scribner and Elmer D. Merrill. In our older manuals the name was *Setaria*, and the three or four introduced species are very familiar. The name Setaria being untenable, the plants were called *Chamæraphis* Kuntze, not R. Br., and then *Ixophorus* Nash, not Schlecht, and now *Chætochloa* Scribner. In North America there are twenty-eight species of the genus, six of them being described as new in this bulletin. There are twenty-three natives, and of the five introduced European species three are cosmopolitan weeds.— J. M. C.

THE two previous fascicles of the *Flora of the West Indies*[6] have already been noticed in this journal. The third fascicle, just published, completes the first volume, making a book of 536 pages, and contains the following papers; Botanical bibliography of the West Indies, by Urban; Araliaceæ, by Urban; Polygonaceæ, by Lindau; Asclepiadaceæ, by Schlechter; new species, especially Porto Rican, by Urban; Eriocaulaceæ, by Ruhland; Juncaceæ, by Buchenau; and Sabiaceæ, by Urban. Some conception of the unworked condition of the West Indian flora may be gained from the fact that Urban's paper on the new species (especially Porto Rican) occupies over 190 pages. *Syngonanthus* is a new genus of Eriocaulaceæ, containing three species formerly referred to Pæpalanthus.

The first fascicle of the second volume contains a supplementary paper (7 pp.) by Urban upon the botanical bibliography of the West Indies, twenty-seven titles being added. The rest of the fascicle (153 pp.) contains the Cyperaceæ, by C. B. Clarke, twenty-four of the twenty-six genera being presented. The large genera are Rhynchospora (56 spp.), Scleria (30 spp.), Cyperus (27 spp.), Eleocharis (27 spp.), and Mariscus (21 spp.), the great genus Carex being represented by only six species.— J. M. C.

[6] URBAN, IGNATIUS: Symbolæ Antillanæ seu fundamenta floræ Indiæ occidentalis. Vol. I. fasc. III, pp. 385–536; Vol. II. fasc. I. pp. 1–160. Berlin: Gebrüder Borntræger. 1900.

A NOTABLE PAPER in the forthcoming 19th annual report of the U. S. Geological Survey is that by Professor Lester F. Ward upon "The Cretaceous formation of the Black Hills as indicated by the fossil plants," with the collaboration of Walter P. Jenney, Wm. M. Fontaine, and F. H. Knowlton. The paper contains 192 pages of text and 116 plates, those illustrating the species of Cycadeoidea (101 in number) being fine half tones. The plants are considered under four heads: (1) fossil cycadean trunks, (2) fossil forests, (3) other Lower Cretaceous plants, and (4) plants from the Dakota group. The surprising development of cycads in the region of the Black Hills is the subject of special interest to botanists. In 1894 Professor Ward described the seven cycadean species then known from Maryland, but the present paper contains the descriptions of twenty-two species from the Black Hills. These American forms all belong to the genus Cycadeoidea (really identical with Bennettites), which is not now regarded as a true cycad, but as forming a distinct gymnosperm group, Bennettitales, coordinate with Cycadales, etc. The whole paper is full of material for the botanist interested in the history or phylogeny of plant groups.— J. M. C.

FOLLOWING the discovery of the numerous gigantic species of Cycadeoidea (Bennettitales) from the Cretaceous of the Black Hills, described by Professor Ward in the 19th annual report of the U. S. Geological Survey, there comes an account of a rich discovery of cycads in the Jurassic of Wyoming (Carbon county). The forms are small and bulbous, and are thought by Professor Ward to constitute a new genus, which he calls *Cycadella*, and under which he describes no less than twenty species. The great feature of the genus seems to be a peculiar outer covering which completely invests and cuts off from view the usual cycadean armor. The statement is that "Cycadella developed an exuberant growth of fine scales or hairs from the bases of its old petioles below the apex, which formed a woolly or mossy covering of considerable thickness, sufficient when tightly appressed to the trunk and petrified there to form a layer 5–15^{mm} thick all over the fossil trunks." The paper appears in Proc. Washington Acad. Sci. 1: 253–300. 1900, and is illustrated by eight half tone plates.—J. M. C.

ALMOST a century ago (1806–1813) Sibthorp and Smith published their *Floræ Graecæ Prodromus*, and in his *Flora Orientalis* Boissier made such additions as exploration of certain minor regions made necessary. In fact, our knowledge of the Grecian flora has been very incomplete. To supply this lack Wilhelm Engelmann has undertaken the publication of a complete flora of Greece by Dr. E. de Halácsy,[7] than whom no one is more competent, as he possesses abundant material, has traversed the country a number of

[7] HALÁCSY, E. DE: Conspectus Floræ Graecæ. Vol. 1. Fasc. 1. pp. 1–224. Leipzig: Wilhelm Engelmann. 1900. *M* 5.

times, and has already published a number of memoirs upon the subject. The *Conspectus* will be entirely in Latin, and will enumerate with full description, synonymy, and habitat, all the plants of political Greece, with its isles, and also of Epirus and Crete. The work will appear in eight to ten fascicles, each containing about 160 pages, and will be completed in five or six years. The cost of the whole work will not exceed 30 marks, or 38 francs. The preface, bibliography, and keys will appear with the last fascicle. The first one includes Ranunculaceæ to Alsinaceæ, and the sequence is that of Bentham and Hooker.—J. M. C.

THE LAST "Contribution from the Gray Herbarium of Harvard University" appears as *Proc. Am. Acad.* **35**: 307–342. 1900, and contains four papers. The first is by J. M. GREENMAN, entitled "New species and varieties of Mexican plants," and contains descriptions of twelve new species.—The second is by B. L. ROBINSON, entitled "Synopsis of the genera Jaegeria and Russelia." The species of Jaegeria have been much confused with Sabazia, Galinsoga, Melampodium, and Spilanthes. Dr. Robinson recognizes nine species, two of which are new. The genus Russelia contains thirteen species, two of which are new.—The third paper is by E. B. ULINE, entitled "New Dioscoreas from Mexico," and contains descriptions of two species and a new variety.—The fourth paper is by B. L. ROBINSON, entitled "New phanerogams, chiefly Gamopetalae, from Mexico and Central America," and deals chiefly with new species (twenty in number) and specific reductions in the genus *Eupatorium*.—J. M. C.

THE fourth fascicle of Engler's work on the genera and families of African plants[8] has just appeared, completing the Combretaceæ. Notices of the preceding fascicles appeared in the BOTANICAL GAZETTE for January 1899 and January 1900. In the third fascicle a synopsis of Combretaceæ and an elaboration of the greatest genus, *Combretum*, were given. In the present fascicle the nine other African genera are presented, by far the largest being *Terminalia*, with 45 species, 22 of which are described as new. The fascicle is a model of completeness and fine presentation, the plates and figures being especially worthy of commendation. The general conclusions in reference to the African Combretaceæ, apart from those littoral species which belong to the mangrove-formation, is that there is very little relation with either tropical America or Madagascar, but that there is a rich development of endemic groups in the various plant-formations of tropical Africa.—J. M. C.

JANET R. PERKINS has published a "Monograph of the genus Mollinedia," being a dissertation for the doctorate at the University of Heidelberg.

[8] ENGLER, A.: Monographien afrikanischer Pflanzen-familien und -Gattungen. IV. Combretaceæ excl. Combretum, bearbeitet von A. Engler and L. Diels. 4to. pp. 44. *pls.* 15. *figs.* 5. Leipzig: Wm. Engelmann. *M* 12.

The genus belongs to the Monimiaceæ, and is peculiar to tropical America, with its greatest development in southern Brazil. In 1868, in his monograph of the genus for the *Prodromus*, A. DeCandolle recognized 28 species, two of them being regarded as doubtful. In the present monograph 71 species are presented, 46 of them being described for the first time.— J. M. C.

A REVISION of the North American species of *Euphorbia* § *Tithymalus* has been published by J. B. S. NORTON in the 11th annual report of the Missouri Botanical Garden, illustrated by 42 plates. Thirty-six species are recognized, eight of them introduced from Europe, and one of them new. The section contains about 400 species of the 700 or more that have been described, but is rather poorly represented in America, the greater number being southwestern and xerophytic.— J. M. C.

NOTES FOR STUDENTS.

MR. FRANCIS E. LLOYD is making a vigorous study of the comparative embryology of the Rubiaceæ. His first paper[9] outlines the task before him and discusses the development of *Vaillantia hispida*, one of the Galieæ indigenous to the Mediterranean region, from earliest stages to mature fruit, paying special attention throughout to the matter of nutrition. The chief characteristics of this species are: a multicellular archesporium; a single integument; migration of the megaspore mother cell and development in the micropyle; great development of antipodals for the sake of securing food to the growing embryo-sac, and the development of a suspensor with cells clustered like a "bunch of grapes," which breaks down with the appearance of the cotyledons. There is found an abundant source of food supply and an efficient means of transmitting it during every stage of development, until finally the plant by way of the vascular region deposits a supply of starch and cellulose in the tissues surrounding the mature embryo.—J. E. WEBB.

BARANETZKY, to whom we owe an improved form of the registering auxanometer, describes[10] a new apparatus for recording the periodic curvatures of leaves and stems. The registering apparatus itself consists of a drum, carrying smoked paper, and rotated by clockwork once in twenty four hours. The writing point, a bit of flexible metal, is attached to a vertical belt, longer than the drum, passing over pulleys actuated in opposite directions by one or the other of two electromagnets on the base. The leaf stalk or stem to be studied is fastened to a swinging lever which actuates a train of three wheels by which the movements are magnified. The third axle carries a spur wheel, which, by bending aside a flexible platinum strip,

[9] LLOYD, F. E.: The comparative embryology of the Rubiaceæ. Bull. Torr. Bot. Club **8**: 1–25. *pl. 1–3*. 1899.

[10] Berichte d. deutsch. bot. Gesells. **17**: 190. 1899.

closes an electric circuit through one or the other of the electromagnets. One electromagnet, actuating one of the pulleys over which the belt passes, raises the writing point, while the other lowers it, thus recording a corresponding deflection of the organ. In the instrument used by Baranetzky a deflection of 1° was recorded by a 2 mm step in the record line. He thinks the instrument capable of twice as great sensitiveness.—C. R. B.

HOFMEISTER in his description of the Balanophoraceæ, which reappears in the text-books,[11] describes the pistil as a carpel containing a single integumented ovule, attached laterally near the top; fertilization attends the introduction of a pollen tube; a five to eight-celled embryo develops and is attached to the wall of the sac by a suspensor. After a cursory examination of *Balanophora Indica*, using material secured from India, van Tieghem[12] declares that there is no ovule or placenta; that the megaspore is plunged into the tissue at the base of the style; that there is no fusion of polar nuclei, and that fertilization occurs rather indifferently at either the sexual or the antipodal end of the sac. Treub[13] has now published a very close series of figures from earliest stages to mature fruit, drawn from sections of *B. elongata* which occurs abundantly in the neighborhood of the Buitenzorg Gardens in Java. Treub finds no ovule or placenta; there is an epidermal growth above the embryo-sac designated as the style; the polar nuclei do not fuse and the development of the endosperm invariably results from growth and division of the polar cell of the egg apparatus. Periclinal walls cut off a cell in the midst of the endosperm which develops into a five to ten-celled pseudo-embryo. Treub decides against fertilization, but in a species in which staminate flowers occur. Dr. Lotsy,[14] however, confirms him in every particular, including non-fertilization, from observations upon *B. globosa*, a species which, in his neighborhood at least, has no staminate flowers. He objects to using the word "style" at all in comparing this curious organ with the floral structures of other plants. For hints with regard to the course of reduction and its point of departure both Treub and Lotsy look forward to the study of *Rhopalocnemis phalloides* Jungh. and other forms. Dr. Lotsy is very anxious that *Balanophora Indica* be worked over again with much care, and perhaps with special reference to cytological problems.—J. E. WEBB.

[11] ENGLER and PRANTL: Natürlichen Pflanzenfamilien III. 1: 261. SCHENK: Handbuch 3^1: 369.

[12] VAN TIEGHEM, PH.: Sur l'organisation florale des Balanophoracées. Bull. Bot. Soc. de France **43**: —. 1896.

[13] TREUB, MELCHOIR: L'organe femelle et l'apogamie du *Balanophora elongata*, Bl. Ann. Jard. Buitenz. **15**: 1–22, *pl. 1–8*.

[14] LOTSY, DR. J. P.: *Balanophora globosa* Jungh. Ann. Jard. Buitenz. II. 1: 174–186, *pl. 26–29*. 1899.

AN UNUSUAL paper has appeared on *Drosera rotundifolia*. It is a cytological and physiological study of this interesting plant by Otto Rosenberg[15] of Stockholm, whose investigations were conducted chiefly at Bonn. The examination is suggestive of methods of study in cytology that are soon likely to come to the front, namely, studies upon protoplasm that has been subjected to various conditions in the attempt to analyze the factors that influence its minute structure.

The paper is divided into two parts: the first, on forms of nuclear division, and the second, on the physiological behavior of the nucleus. The first part considers mitoses in various tissues, reproductive and vegetative. One notes that the spindles in vegetative cells are developed from caps of kinoplasm, and in the pollen mother cell the presence of a delicate zone of granular kinoplasm and fibrillæ encircling the nucleus indicates the beginning of the achromatic part of the nuclear figure. However, the account of karyokinesis in the pollen mother cell is not sufficiently detailed to offer evidence on disputed points; it appears that the nucleus is small and not altogether satisfactory for such a study.

Of the physiological studies upon the nucleus the most interesting are naturally those on the cells in the tentacles of the leaf. The most fruitful studies consisted of an examination and comparison of certain epidermal cells before and at successive intervals after the leaves had been fed with various substances. These experiments were tried with a variety of foods, such as albumen, peptone, meat, cheese, sugar, bread, hæmoglobin, and other organic substances, and with such inorganic salts as borax, calcium nitrate, calcium phosphate, and ammonium oxalate.

Feeding the leaves with organic material brings about very shortly changes in the cytoplasm and nucleus in the epidermal cells of the tentacles. Peculiar granules appear in the cytoplasm near the nucleus, and the tannin vacuoles become more prominent. But the most conspicuous effects are exhibited in the nucleus. The chromatin increases greatly in quantity along the linin network, and finally collects as longer or shorter rods on the membrane. Finally, when the reactions are most energetic, the chromatin takes the form of a thick thread and the linin network cannot be followed. The nucleolus during this process of feeding usually grows smaller and smaller until it is very insignificant. But there is no fixed relation between the decrease in the size of the nucleolus and the great increase in the amount of chromatin.

These reactions affect other cells in the tentacle, those of the endodermis and stalk exhibiting similar changes.

In general one may say that the feeding of a leaf almost always results in

[15] ROSENBERG, O.: Physiologisch-cytologische Untersuchungen über *Drosera rotundifolia* L. Upsala 1899.

the excretion from the epidermis of slime, and this is accompanied by decrease in the amount of cytoplasm and usually by a great increase in the chromatin, while the nucleolus becomes smaller. The investigations point to the nucleus as the chief center in the cell, initiating and carrying out the complex chemical and physical reactions.

There is much detail in this paper of 116 pages and apparently a very complete summary of the literature, together with much suggestive speculation interesting to the student of the plant cell.— B. M. DAVIS.

ITEMS OF TAXONOMIC interest are as follows: A. W. EVANS (Bull. Torr. Bot. Club **27**: 97–104. 1900) has described a new genus of Hepaticae (*Acromastigum*) from the Hawaiian islands, heretofore referred with doubt to Mastigobryum (Bazzania).— E. L. MORRIS (*ibid.* 105–119) has published a revision of the species of Plantago commonly referred to *P. Patagonica* Jacq., in which fifteen species are recognized, six of them being described as new.— E. B. ULINE (Field Columbian Mus. Bot. Series **1**: 413–422. *pls. 22–24.* 1899) has described a new genus (*Higinbothamia*) of Dioscoreaceæ from Yucatan, a new Dioscorea, and five new species of Amaranthaceæ.— In the current number of Engler's *Botanische Jahrbücher* (**28**: 145–272. 1900) the present series of papers (XIX) on the African flora is completed. E. GILG describes a new genus (*Brachythalamus*) of Thymelæaceæ; E. GILG and K. SCHUMANN describe a new genus (*Maschalocephalus*) of Rapateaceæ; TH. LOESENER publishes his third paper on African Celastraceæ; F. KRÄNZLIN presents the African Orchidaceæ, describing two new genera (*Angraecopsis* and *Schwartzkopffia.*) In the same number P. HENNINGS publishes a list of Japanese fungi, describing a new genus (*Hydnofomes*) of Hydnaceæ.— In *Deutsch Bot. Monats.* (**18**: 26–27. 1900) W. N. SUKSDORF publishes three new species of Saxifraga, and a new variety of *Vicia Americana*, all from Washington.— J. M. C.

NEWS.

DR. HERMAN AMBRONN, of Leipzig, has been called to a professorship in the University of Leipzig.

THE French Academy of Sciences has elected as corresponding members in the section of botany Professors Schwendener and Pfeffer, in place of Baron Müller and Professor Cohn, deceased.

PROFESSOR A. S. HITCHCOCK, of Kansas Agricultural College, has been elected director of the *Académie internationale de géographie botanique* for 1900, succeeding Casimir DeCandolle. A portrait is published in the *Bulletin* for March.

M. ADRIEN FRANCHET died suddenly on February 15 in his sixty-sixth year. He is best known as the author of the *Flore de Loire-et-Cher*, monographs of Verbascum and Strophanthus, the *Flore du Japon*, the *Plantae Davidanae*, the latter the elaboration of the collections of the abbé David in Mongolia and eastern Thibet, and the *Sertum Somalense*.

AT THE meeting of the Academy of Science of St. Louis on March 19, 1900, Mr. H. von Schrenk exhibited some burls on the white spruce (*Picea Canadensis*). The burls, unlike most of those so far known, are almost round, and are covered with smooth bark. They grow of various sizes, and occur on the trunk and branches of a group of spruces limited to a small area. The wood fibers are arranged in annual rings; they differ from normal wood fibers because of their thinner walls and greater internal diameter, giving the wood a spongy character. Long rows of secondary resin passages occur in each ring. The largest burls, which are from one to three feet in diameter, have rows of long holes within each ring. These holes are diamond-shaped in cross-section, the longer diameter extending radially. Between the holes the wood fibers are compressed tangentially. The speaker explained that the holes must have resulted from an excessive radial pressure exerted from without, probably by the bark. No holes were found where the bark pressure had been released, *i. e.*, where the bark had burst. These results are not in harmony with the findings as to bark pressure reached by Krabbe. The speaker described the manner in which burls are usually formed, and showed the way in which these burls form, by excessive growth, induced by a wound or branch stump.—WILLIAM TRELEASE, *Secretary*.